# ORGANIC SYNTHESES

AN ANNUAL PUBLICATION OF SATISFACTORY
METHODS FOR THE PREPARATION
OF ORGANIC CHEMICALS

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# PREFACE TO VOLUME III

The aims underlying the publication of this series have been made clear in the introductions in the first and second volumes. The program therein outlined has been adhered to, and efforts have been made to obtain and include as many contributions as possible from chemists other than the members of the Editorial Board. Thus out of the twenty-five preparations in Volume II, nine were provided by eight contributors; while in the present volume, thirteen contributors have supplied seventeen preparations out of a total of thirty. It is hoped that the number of contributors will continue to increase in subsequent volumes; and organic chemists not only in this country but abroad, are cordially invited to contribute work which they regard as suitable.

The Index in this volume refers to subjects not only in Vol. III but in Vols. I and II as well. It is planned to continue this collective Index in subsequent volumes.

The editors desire to express their sincere appreciation of the criticisms and corrections which have been extended, and their hope that this form of cooperation will be freely offered in the future as in the past. Their intention is to take advantage of all suggestions in the preparation of new editions.

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COIMBATO

# ORGANIC SYNTHESES

## I

### ACETAL

$$CH_3 \cdot CHO + 2C_2H_5OH \rightarrow CH_3 \cdot CH(OC_2H_5)_2 + H_2O$$

Prepared by Homer Adkins and B. H. Nissen.
Checked by H. T. Clarke and J. H. Bishop.

#### 1. Procedure

In a 1-gallon bottle are placed 1050 g. of 95 per cent ethyl alcohol and 200 g. of granulated anhydrous calcium chloride (Note 1). The mixture is cooled to 8° or below by immersion in ice water, and 500 g. of freshly distilled acetaldehyde (B. P. 20–22°) is slowly added down the sides of the bottle so that it forms a layer on the alcoholic calcium chloride. The bottle is then tightly closed with a cork stopper and shaken vigorously for a few minutes (Note 2). It is then allowed to stand at room temperature with intermittent shaking for one to two days. The mixture divides into two layers after one to two hours; after the first twenty-four hours no appreciable change in volume of the two layers takes place.

The upper layer, which weighs 1280–1285 g., is separated and washed with 1000 cc. of water in three equal portions. The weight has now fallen to 990–995 g. The oil is dried by standing over 25 g. of anhydrous potassium carbonate and is then fractionally distilled with the use of an efficient column at least 90 cm. long (Note 3), and the fraction which boils at 101–103.5° collected as pure acetal. In this way 700–720 g. can be obtained by one or

two fractionations. The yield can further be increased by washing the low-boiling fractions and residue with small quantities of water, drying, and again fractionally distilling, so that a total of 790–815 g. is obtained (61–64 per cent of the theoretical amount).

## 2. Notes

1. It is essential that the calcium chloride should be anhydrous; if it contains water of crystallization, stratification may be long delayed and the yield be much decreased. On the other hand, no great advantage is observed by substituting absolute alcohol for the 95 per cent material.

2. On mixing the acetaldehyde and the alcoholic calcium chloride solution, a considerable rise in temperature takes place; for this reason it is necessary to chill the reagents and to close the stopper before mixing intimately; otherwise losses might occur by volatilization.

3. A fractionating column containing a condensing unit at the head [1] has been found satisfactory.

## 3. Other Methods of Preparation

Acetal has generally been prepared by the action of aldehyde upon alcohol in the presence of small quantities of mineral acid; [2] a patent has recently appeared [3] in which the formation of a 90 per cent yield of acetal by the action of certain metallic salts is claimed, but it has been found impossible to duplicate this result,[4] while the presence of mineral acid has been shown to act adversely on the yield.

[1] Ind. Eng. Chem. **15**, 349 (1923).
[2] Ann. **126**, 62 (1862); Ber. **30**, 3053 (1897).
[3] Brit. Pat. 101,428 (1916); U. S. Pat. 1,312,186 (1919); C. A. **11**, 86 (1917).
[4] J. Am. Chem. Soc. **44**, 2749 (1922).

II

## ACETAMIDE

$$CH_3 \cdot CO_2NH_4 \rightarrow CH_3 \cdot CONH_2 + H_2O$$

Prepared by G. H. Coleman and A. M. Alvarado.
Checked by H. T. Clarke and E. R. Taylor.

### 1. Procedure

In a 5-l. flask is placed 3 kg. of glacial acetic acid and to this is added a weight of ammonium carbonate corresponding to 400 g. of ammonia (Note 1). The flask is fitted with a one-hole stopper holding an efficient fractionating column 90 cm. long with condenser and receiver. An air condenser 150–200 cm. long may be employed. The mixture in the flask is heated to gentle boiling and the flame so regulated that the rate of distillation does not exceed 180 cc. per hour. The distillation is continued in this way for eight to ten hours, until the temperature at the head of the column reaches 110°. The distillate, which is a mixture of water and acetic acid, amounts to 1400–1500 cc. The receiver is changed, the flame under the flask is gradually increased, and the distillation is continued at about the same rate until the temperature at the head of the column rises to 140°. The distillate, which amounts to 500–700 cc., is largely acetic acid and may be used in the next run.

The contents of the flask are transferred to a 2-l. flask for fractional distillation (as described in Vol. I, p. 40), having a column 40–50 cm. long, and distilled under atmospheric pressure, using an air condenser. The fraction boiling below 210°, amounting to 250–300 cc., is collected separately. The material remaining in the flask is nearly pure acetamide and may all be distilled, 1150–1200 g. passing over at 210–216°. By redistilling the fraction boiling below 210°, the yield may be

increased to 1200–1250 g. (87–90 per cent of the theoretical amount). The acetamide thus obtained is pure enough for most purposes, but if a purer product is desired it may be recrystallized from a mixture of benzene and ethyl acetate; 1-l. of benzene and 300 cc. of ethyl acetate are used for 1 kg. of acetamide. Colorless needles melting at 81° are thus obtained (Note 2). The solvent and the acetamide it contains may be recovered by distillation.

## 2. Notes

1. Ammonium carbonate of commerce is often extremely impure, and care must be taken to obtain a representative sample for the determination of the ammonia content by titration with standard acid. The ammonium carbonate used in this preparation contained 27.2 per cent of ammonia, and 1470 g. was used in each run.

2. As acetamide is somewhat hygroscopic, it cannot be exposed to the air unless precautions are taken to have the air dry.

## 3. Other Methods of Preparation

Acetamide has been prepared by a variety of methods, of which the more important are the following: by the rapid distillation of ammonium acetate;[1] by heating ammonium acetate in a sealed tube and distilling the product;[2] by treating acetic anhydride with ammonia;[3] by heating a mixture of ammonium chloride and sodium acetate to 240°;[4] by the action of cold aqueous ammonia on ethyl acetate;[5] by boiling a mixture of glacial acetic acid and ammonium thiocyanate for four days;[6] by saturating glacial acetic acid with dry ammonia and boiling;[7] by distillation of ammonium acetate through a reflux condenser

[1] Ann. **105**, 277 (1858).
[2] Ber. **15**, 977 (1882).
[3] Ann. chim. phys. (3) **37**, 327 (1853).
[4] J. Am. Chem. Soc. **24**, 762 (1902).
[5] Am. J. Sci. (4) **24**, 429 (1907).
[6] J. prakt. Chem. (2) **27**, 514 (1883).
[7] J. Am. Chem. Soc. **39**, 933 (1917).

filled first with glacial acetic acid and then with aniline until the temperature of the mixture reaches 220°.[8]

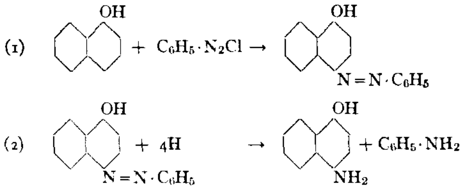
The foregoing process is based on the method of W. A. Noyes and W. F. Goebel,[9] in which equimolecular proportions of ammonium acetate and acetic acid are heated together, the acetic acid having been shown to accelerate both the dehydration of ammonium acetate and the hydrolysis of acetamide.

[8] J. Pharm. Chimie (6) **23**, 230 (Chem. Zentr. 1906 i, 1098).

[9] J. Am. Chem. Soc. **44**, 2286 (1922).

III

# 1,4-AMINONAPHTHOL HYDROCHLORIDE



Prepared by J. B. Conant, R. E. Lutz, and B. B. Corson.
Checked by H. T. Clarke and J. H. Bishop.

## 1. Procedure

In a 6-l. wide-mouth bottle, fitted with a mechanical stirrer and a separatory funnel, are placed 200 g. of α-naphthol melting at 91° or higher (Note 1) and 910 cc. of 10 per cent sodium hydroxide solution. The mixture is stirred for ten minutes, at the end of which time it has become a homogeneous solution.

While the naphthol is dissolving, a solution of benzenediazonium chloride is prepared. In a 3-l. wide-mouth bottle are placed 128 g. of aniline and 1.5 kg. of cracked ice, and on to this mixture while it is stirred (by hand) is poured 410 cc. of concentrated hydrochloric acid (32 per cent; sp. gr. 1.16). Some crystals of aniline hydrochloride separate at this point. A solution of 100 g. of sodium nitrite in 200 cc. of water is now run in slowly from a 500-cc. separatory funnel. The tip of the stem of the separatory funnel should dip well below the surface of the liquid. The mixture is stirred (by hand if desired) and a drop is tested from time to time with starch iodide paper. This is

best done by diluting the test-drop on a watch glass with about 1 cc. of water and then placing a drop of this solution on the starch iodide paper. The sodium nitrite solution is added until there is a test for nitrous acid which is permanent for five minutes. The diazotization is then complete; all but 2–5 per cent of the nitrite is required.

To the alkaline solution of α-naphthol is now added 1 kg. of cracked ice, the stirrer is started and the diazonium solution run in through a separatory funnel, the stem of which dips below the surface of the solution. The stirring must be uniform and efficient during the addition (Note 3). The addition of the diazonium solution should take ten minutes. Ice is added if necessary to keep the solution below 10°. The mixture is stirred for half an hour after the addition of the diazonium solution and then allowed to stand for three hours at 7–10° (Note 4), and finally filtered on a Buchner funnel, washed with a liter of water and sucked as dry as possible.

The moist benzeneazo-α-naphthol is next transferred to a 5-l. wide-mouth bottle or a 2-gal. crock equipped with a mechanical stirrer and containing 3 l. of 10 per cent sodium hydroxide solution. The mixture is stirred for ten minutes to insure solution of the dye, and then filtered. The insoluble solid is stirred up with 500 cc. of 10 per cent sodium hydroxide, filtered again and washed with water. The solid, which weighs 10–90 g., consists mainly of the 2,4-disazo derivative (m. p. 197–198°), together with any benzeneazo-β-naphthol that may be present.

To the deep-red solution is added 550 g. of sodium hydrosulfite (of at least 80 per cent purity); the mixture is stirred for five minutes and then for five 30-second periods during half an hour (Note 5). The solution slowly loses its red color (a thin layer of aniline collects on the surface), and the temperature rises from 25° to 50°. At the end of half an hour the solution should no longer be red; it is then rapidly cooled to 20° in a freezing bath and by the addition of about 500 g. of ice.

To the solution is now added, with stirring, 625 cc. of concentrated (32 per cent; sp. gr. 1.16) hydrochloric acid (Note 6) or its equivalent of acid of approximately the same strength.

A cream-colored precipitate of the aminophenol forms. It is rapidly filtered off on a Buchner funnel (Note 7) and washed with one portion (200 cc.) of water about half saturated with sulfur dioxide. The precipitate soon darkens on exposure to air and is therefore rapidly transferred to a 2-gal. crock containing 2 l. of water and 340 cc. of concentrated hydrochloric acid. The soft lumps are broken up with a cork stopper set on the end of a stirring rod. Steam is passed into the mixture for 45 minutes, and during the last 30 minutes the mixture is stirred mechanically. At the end of this time the amine will have passed completely into solution. An insoluble impurity weighing 25–30 g. is removed by filtering with suction. The filtrate is cooled to 25° and if it is not clear is filtered again. To the clear solution at 25° is added 1200 cc. of concentrated hydrochloric acid with stirring, when a light gray precipitate of the aminophenol hydrochloride immediately forms. The solution is allowed to stand for two to three hours and is then filtered with suction. The hydrochloride is sucked as free from mother liquor as possible, washed with a little hydrochloric acid (1 vol. acid to 1 vol. of water), and dried on a porous plate. The liquors are concentrated to small volume under reduced pressure, and a second crop is thus obtained. The product is of a light purplish tint (Note 8) and weighs 175–200 g. (65–74 per cent of the theoretical amount, based on the quantity of α-naphthol employed).

## 2. Notes

1. Technical α-naphthol varies widely in purity, but material melting at 91° or above is substantially free of β-naphthol; unsatisfactory results will be obtained with material of an inferior grade, but when not more than 2 per cent of β-naphthol is present yields of 70 per cent should readily be obtained.

2. During the diazotization of the aniline the temperature must be kept at 0–5°. The amount of ice given above is usually enough for this, but if not, more must be added.

3. The stirring must be very uniform and vigorous during the addition of the benzenediazonium chloride solution to the

α-naphthol; otherwise the precipitate collects in gummy balls. If properly carried out, the operation produces a fine red precipitate which filters easily and is not at all gummy.

4. The temperature at which the coupling takes place and the mixture is allowed to stand has a great influence on the amount of disazo compound formed, as much as 120 g. being produced if no external cooling is provided.

5. The reduction with hydrosulfite may be carried out in an atmosphere of illuminating gas or hydrogen sulfide. The first precipitate of the free aminophenol is a little lighter in color when prepared in an inert atmosphere but the final aminonaphthol hydrochloride has the usual light purple color.

6. If too much hydrochloric acid is added in the precipitation of the free aminophenol, some will, of course, redissolve. The amount given above will give satisfactory results if the indicated quantities are adhered to.

7. The completeness of the precipitation should be tested by adding a little acid to one portion of the filtrate and a little sodium carbonate olution to another; no further precipitate should be produced in either case.

8. The aminophenol hydrochloride can be further purified by dissolving in hot water, cooling, and adding concentrated hydrochloric acid. It crystallizes in beautiful crystals, but the light violet color is very difficult to remove.

### 3. Other Methods of Preparation

1.4-Aminonaphthol has been prepared by the reduction of 1.4-nitronaphthol by tin and hydrochloric acid;[1] by the reduction with sodium amalgam of 1,4-aminonaphthol-3,8-disulfonic acid[2] or 1,4-aminonaphthol-5-sulfonic acid;[3] by the action of phenylhydrazine on 1,4-nitrosonaphthol.[4] The more usual preparative method has been to start with α-Naphthol Orange (Orange I) and reduce it with stannous chloride.[5]

[1] Ann. **183**, 247 (1876).
[2] Ber. **28**, 1536 (1895).
[3] Ann. **393**, 211 (1912).
[4] Gazz. Chim. Ital. (2) **25**, 393 (1895).
[5] Ber. **25**, 423 (1892); J. prakt. Chem. (2) **62**, 31 (1900); Ann. **211**, 61 (1882).

## IV

## *p*-AMINOPHENYLACETIC ACID

$$NO_2 \cdot C_6H_4 \cdot CH_2 \cdot CO_2H + 3(NH_4)_2S + 3H_2O \rightarrow NH_2 \cdot C_6H_4 \cdot CH_2 \cdot CO_2NH_4 + 3S + 5NH_4OH$$

$$NH_2 \cdot C_6H_4 \cdot CH_2 \cdot CO_2NH_4 + CH_3 \cdot CO_2H \rightarrow NH_2 \cdot C_6H_4 \cdot CH_2 \cdot CO_2H + CH_3 \cdot CO_2NH_4$$

Prepared by G. Ross Robertson.
Checked by H. T. Clarke and J. H. Bishop.

### 1. Procedure

A 1500-cc. flask is fitted with a two-hole rubber stopper carrying a glass tube which ends below the middle of the flask. The second hole is fitted with a common glass stopcock (Note 1). To the flask is added 500 cc. of 6-N ammonium hydroxide (sp. gr. about 0.95), and 100 g. of *p*-nitrophenylacetic acid (Vol. II, p. 59) is now slowly introduced, with shaking. The flask is then placed in an ice bath, and the mixture saturated with hydrogen sulfide, the temperature being held below 50°.

The stopper is now removed from the reaction flask, and the solution (of ammonium *p*-aminophenylacetate) gently boiled under the hood until nearly all the excess hydrogen sulfide and ammonia have escaped. The solution changes from a dark orange-red to a pale yellow. The deposited sulfur is filtered off by suction, and 40 cc. of glacial acetic acid rapidly stirred into the hot filtrate. The *p*-aminophenylacetic acid which crystallizes out weighs 69–70 g., but it is contaminated with a small amount of free sulfur. On evaporating the mother liquor to a small volume, about 5 g. more can be obtained. The crude material is recrystallized from 4 l. of distilled water, 69–70 g. (83–84 per cent of the theoretical amount) of a product which melts at 199–200° being thus obtained.

## 2. Notes

1. The use of a stopcock in the reaction flask during the saturation with hydrogen permits the occasional expulsion of hydrogen gas, which would otherwise accumulate. Apparently, commercial ferrous sulfide contains free iron as an impurity.

2. The procedure avoids the troubles of filtration incidental to the method of reduction with ferrous sulfate and ammonia, and the yield is better. Inasmuch as the only by-product is the very soluble ammonium acetate, a large yield can be secured by close evaporation.

## 3. Other Methods of Preparation

*p*-Aminophenylacetic acid has been made by the hydrolysis of *p*-aminobenzyl cyanide[1] with concentrated hydrochloric acid; by the reduction of *p*-nitrophenylacetic acid with tin and hydrochloric acid,[2] or with ferrous sulfate and ammonia.[3]

[1] Ber. **17**, 237 (1884); **15**, 835 (1882).
[2] Ber. **2**, 200 (1869); J. Chem. Soc. **37**, 92 (1880).
[3] J. Am. Chem. Soc. **39**, 1437 (1917); **43**, 180 (1921).

## V

## ARSANILIC ACID

$$C_6H_5 \cdot NH_2 + H_3AsO_4 \rightarrow NH_2 \cdot C_6H_4 \cdot AsO_3H_2 + H_2O$$

Prepared by W. LEE LEWIS and H. C. CHEETHAM.
Checked by OLIVER KAMM and A. O. MATTHEWS.

### 1. Procedure

To 1035 g. of syrupy arsenic acid (80–85 per cent, sp. gr. 2.00/20°; Note 1) in a 12-inch evaporating dish, is added 828 g. (800 cc.) of aniline (Note 2) in 100-cc. portions; meanwhile, the lumps of aniline arsenate which are formed are broken up by rapid stirring with a porcelain spatula. When all the aniline has been added, the powdered solid is transferred to a 3-l. round-bottom flask equipped with a mechanical stirrer, a thermometer reaching to the lower part of the vessel, and a condenser arranged for downward distillation (Note 3); an additional 800 cc. of aniline is added and the flask slowly heated in an oil bath. The bath may be kept at a temperature not exceeding 170–175° as long as there is any considerable amount of unmelted material in the flask. When the contents of the flask have become liquid the temperature of the bath is dropped and the mixture held at 155–160° (inside temperature), with continual stirring, for at least four and a half hours. The mass will have assumed an intense violet color.

The reaction mixture is poured into 700 cc. of water and the flask is washed out with a portion of a previously prepared solution of 330 g. of sodium hydroxide in 1400 cc. of water, the washings being added to the reaction mixture. The remainder of the alkali is then added and the mixture agitated and cooled under the tap. At this point, two distinct layers are present, a lower pink-colored alkaline water layer, and an upper strongly

colored aniline layer. The water layer is, while warm, carefully separated from the purple-colored oil by means of a separatory funnel (heated to prevent the separation of sodium arsanilate) and after treatment with 15 g. of decolorizing carbon, is filtered through paper.

The arsanilic acid can be obtained from the aqueous alkaline solution either as the free acid or as the sodium salt. To obtain the free acid the solution is acidified with concentrated hydrochloric acid until the purple color of tetrabromophenolsulfonphthalein is changed to a faint yellow. Care should be taken, in the addition of the acid, not to overstep the end-point (Note 4). Crystallization is stimulated by scratching and the flask is allowed to stand over night to complete the precipitation. The crystals are filtered off and recrystallized once from water (about 2500 cc.) in order to obtain a white product. If the initial crystals obtained have an appreciable pink tinge, it is advisable to remove most of the color by digesting with a small volume of warm alcohol before crystallization from water is attempted (Note 5).

The yield of purified arsanilic acid obtained according to the above directions amounts to 250–300 g. (Note 6).

## 2. Notes

1. Arsenic acid obtained by oxidizing arsenious oxide with nitric acid is satisfactory; a syrupy acid of 80–85 per cent purity can be obtained on the market.

2. A good commercial grade of aniline, light in color and boiling with not more than 1° range, is suitable. It is not necessary to employ a freshly distilled product.

3. During the reaction a considerable amount of water escapes, together with aniline vapors, from the reaction vessel. The condenser is provided to condense and collect the distillate outside of the reaction flask, and thus minimize any danger from the aniline vapors. About 200 cc. of distillate will be obtained.

4. The precipitation of arsanilic acid from the reaction

mixture may cause difficulty if care is not taken to attain a definite hydrogen-ion concentration. The indicator consists of a 0.5 per cent solution of bromophenol blue. Filter paper dipped into this solution and dried forms a convenient test paper. That concentration which will cause a color change from purple to a faint yellow is considered the end-point. Congo Red may also be used as an indicator, but it is somewhat less sensitive.

5. A highly colored acid is occasionally obtained, and under such circumstances it may become essential to effect its purification by conversion into the sodium salt, followed by precipitation of the hot concentrated solution with alcohol, and regeneration of the acid. Colored impurities may also be eliminated by a process of fractional precipitation during the decomposition of the sodium salt, the impurities being separated with the first 25 g. fraction of the acid.

6. Additional amounts of arsanilic acid may be obtained from the various mother liquors. The products thus obtained are usually rather impure and hence are not considered in the yields quoted. On larger scale production it would be economical to recover this material as well as the excess aniline.

7. In preparing arsanilic acid upon a larger scale it was found that doubling the amount of aniline used and continuing the heating at 155° during twelve to sixteen hours resulted in a yield of 350–400 g. of recrystallized acid. For small scale work, when aniline is not recovered and when time is an important factor, the directions as presented seem preferable, particularly so since the arsanilic acid prepared during a short heating period is purified more readily.

### 3. Other Methods of Preparation

Arsanilic acid was prepared by Bechamp [1] by heating aniline arsenate to 190–200°. The product was originally described as the anilide of arsenic acid, but Ehrlich and Bertheim [2] showed its structure to be that of a true aryl arsenic acid.

[1] Compt. rend. **56**, (1) 1172 (1863).
[2] Ber. **40**, 3292 (1907).

The feasible methods of preparing arsanilic acid all depend upon the interaction between aniline and arsenic acid. Various temperatures ranging from 150 to 200° and various ratios of aniline to arsenic acid have been recommended.[3]

The main objection to most of the published methods is the fact that the authors leave it to be inferred that this is a smooth reaction. None of them points out the fact that an important side-reaction consists in the oxidizing action of arsenic acid upon aniline, with the production of a deeply purple-colored dye as well as much tarry material and some diaryl arsenic acid.

[3] Ber. **49**, 239 (1916); J. Am. Chem. Soc. **41**, 451 (1919); **42**, 828 (1920).

VI

## BENZALACETONE

$$C_6H_5 \cdot CHO + CH_3 \cdot CO \cdot CH_3 \rightarrow C_6H_5 \cdot CH = CH \cdot CO \cdot CH_3 + H_2O$$

Prepared by N. L. DRAKE and P. ALLEN, JR.
Checked by C. S. MARVEL and A. W. SLOAN.

### 1. Procedure

IN a 2-l. bottle equipped with a mechanical stirrer are mixed 635 g. (800 cc.) of U. S. P. acetone (Note 2), 420 g. (400 cc.) of freshly distilled benzaldehyde boiling at 178–180° (shaken with dilute sodium carbonate just before distillation), and 400 cc. of water. To this mixture, 100 cc. of 10 per cent aqueous sodium hydroxide is slowly added from a dropping funnel (Note 3), while the solution is stirred and cooled by a water bath. The rate of addition of the alkali is so regulated that the temperature remains between 25 and 31°. This requires thirty to sixty minutes. The mixture is now stirred for two and a quarter hours at room temperature (Note 4). At the end of this time dilute hydrochloric acid is added until the mixture is acid to litmus. The two layers which form are separated in a separatory funnel. The lower aqueous layer is extracted with 100 cc. of benzene, and the benzene solution added to the yellow oil which formed the upper layer in the first separation. This benzene solution is shaken with 100 cc. of water and separated. The benzene is then removed by distilling from a steam bath, and the residue distilled under reduced pressure (Note 5), any water which condenses with the forerun being separated (Note 6). A special distilling flask with a fractionating side-arm (Vol. I, p. 40) is best employed. The material which distils at 148–160°/25 mm., 133–143°/16 mm., or 120–130°/7 mm. weighs 430–470 g. (Note 1); it solidifies to a crystalline mass on stand-

ing, and is pure enough for all practical purposes. On redistillation there is obtained 375–450 g. (65–78 per cent of the theoretical amount) of material boiling at 137–142°/16 mm. or 123–128°/8 mm., which solidifies on standing to crystals which melt at 40–42°.

## 2. Notes

1. Benzalacetone acts as an irritant, and care should be taken that it be not allowed to come in contact with the skin.

2. A large excess of acetone is taken, so as to diminish the formation of dibenzalacetone.

3. If the sodium hydroxide is added too rapidly and without cooling, the mixture darkens and the yield is lowered. The rate of addition is best determined by watching the temperature of the reaction mixture.

4. Instead of stirring the mixture after the addition of the sodium hydroxide, the bottle may be securely stoppered and shaken on a shaking machine for the same length of time.

5. The lower the pressure used in the distillation the less decomposition occurs, and the less residue is left in the distilling flask. This residue contains some dibenzalacetone.

6. The first few cubic centimeters of the distillate have a greenish color, but the rest is light yellow. For this reason it is desirable to collect the first of the distillate separately, if a very light-colored product is desired.

7. On exposure to air benzalacetone gradually turns brown, especially if it is slightly impure. Pure material can be kept for months in an ordinary stoppered bottle without changing color.

## 3. Other Methods of Preparation

Benzalacetone has been obtained in small yield by dry distillation of a mixture of calcium acetate and calcium cinnamate;[1] by heating the sodium derivative of cinnamaldehyde with methyl iodide;[2] by heating cinnamaldehyde and methyl alcohol with zinc chloride;[2] by heating acetone and benzaldehyde with acetic

[1] Ber. 6, 254 (1873).
[2] Ber. 6, 257 (1873).

anhydride or zinc chloride.[3] It is also formed when styrene and acetyl chloride are condensed by means of stannic chloride and the product is treated with diethylaniline;[4] and when the vapors of cinnamic acid and acetic acid are passed together over ferric oxide at 470–490°.[5] The only practical method, however, consists in condensing benzaldehyde and acetone by means of dilute aqueous alkali.[6]

[3] Ber. **14**, 2461 (1881).
[4] Compt. rend. **168**, 1052 (1919).
[5] *Bull.* soc. chim. (4) **15**, 320 (1914).
[6] Ann. **223**, 139 (1884); **294**, 275 (note) (1897).

VII

## BENZOIC ANHYDRIDE

$$C_6H_5 \cdot CO_2H + (CH_3 \cdot CO)_2O \rightarrow C_6H_5CO \cdot O \cdot CO \cdot CH_3 + CH_3 \cdot CO_2H$$

$$C_6H_5 \cdot CO_2H + C_6H_5 \cdot CO \cdot O \cdot CO \cdot CH_3 \rightarrow (C_6H_5 \cdot CO)_2O + CH_3 \cdot CO_2H$$

Prepared by H. T. CLARKE and E. J. RAHRS.
Checked by ROGER ADAMS and P. K. PORTER.

### 1. Procedure

IN a 5-l. flask, provided with a two-hole stopper fitted with a 90-cm. fractionating column[1] and a dropping funnel, are placed 1500 g. of benzoic acid, 1500 g. of acetic anhydride, and 1 cc. of syrupy phosphoric acid. The mixture is very slowly distilled, at such a rate that the temperature of the vapor at the head of the column does not exceed 120° (Note 1). When 250 cc. of distillate has been collected, 250 g. of acetic anhydride is added, and distillation is continued. This process is again repeated, so that in all 2000 g. of acetic anhydride has been taken. Fractionation is then continued, fractions which distil respectively below 120°, at 120–130°, and at 130–140° being collected. Heating is continued until the temperature of the reaction mixture in the flask reaches 270°.

The residue is fractionally distilled under reduced pressure, resulting in the collection of fractions which boil respectively below 165°, at 165–210°, and at 210–220°, all under 19–20 mm. pressure (Note 2). The lower fractions are mixed with the fraction which boils at 120–130°, and distilled as before after the addition of one drop of phosphoric acid, when a further quantity

[1] Ind. Eng. Chem. 15, 349 (1923).

of material boiling at 210–222°/20 mm. is obtained. This fraction, amounting to 1100–1200 g., consists of crude benzoic anhydride. The lower-boiling fractions may be redistilled until they become too small to justify further work.

The fraction which boils at 120–130° under atmospheric pressure is redistilled, yielding further quantities of acetic acid (below 120°) and acetic anhydride (130–140°).

The crude benzoic anhydride (which is apt to supercool without crystallizing) contains a small proportion of an oily impurity which causes the product to turn yellow on standing; it is recrystallized by dissolving in benzene (50 cc. for each 100 g.) then adding just enough petroleum ether to cause a cloudiness (about 100 cc. is required) and chilling, when the pure anhydride separates in perfectly colorless and odorless crystals melting at 43°. The first crop amounts to about 50 per cent of the crude material taken; the mother liquors are freed of solvent by distillation on the water bath, and the residue distilled under reduced pressure, when a further quantity of pure material can be obtained by recrystallizing the distillate boiling at 210–220° 19 mm. If this process is repeated until the mother liquor becomes too small in amount to redistil satisfactorily, the yield of pure benzoic anhydride melting at 43° amounts to 1000–1030 g. (72–74 per cent of the theoretical amount). It is generally more convenient to distil the mother liquors only once or possibly twice, under which conditions a somewhat lower yield is obtained. The remaining mother liquors may then be mixed with a subsequent preparation.

## 2. Notes

1. As it is probable that the equilibria between the two acids and the three anhydrides are established in reactions of relatively low velocity, the distillation must be carried on very slowly, in spite of the catalytic action of the phosphoric acid. The intermediate fractions contain the mixed anhydride, detectable by its odor, which resembles that of acetophenone.

2. Owing to the high boiling-point of the end-product, the second stage must be conducted under reduced pressure. The

temperatures indicated depend, of course, upon the pressure under which the distillation is carried out, and allowances will have to be made for pressures differing materially from 20 mm.

3. Although the yield above quoted is by no means quantitative, the only reason why it should not be made nearly so by continual redistillation of the various fractions in presence of the catalyst lies in the length of time required for the process. This, however, could be avoided if a large number of runs were to be made, when the intermediate fractions could be worked over repeatedly with each subsequent batch, until practically nothing but acetic acid and benzoic anhydride remained.

### 3. Other Methods of Preparation

Benzoic anhydride has been prepared in rather a poor yield by the action of benzoyl chloride on sodium benzoate,[2] barium oxide at 150°,[3] benzoic acid at 160–200°,[4] sodium nitrite,[5] lead nitrate,[6] or anhydrous oxalic acid;[7] also by treating sodium benzoate with phosphorus pentachloride[8] or sulfur chloride.[9] More important methods consist in treating benzotrichloride with sulfuric acid,[10] and in the action of sodium carbonate upon benzoyl chloride in presence of pyridine.[11]

By heating benzoic acid with acetic anhydride in a closed vessel at 220°, a poor yield of benzoic anhydride is obtained;[12] a 50 per cent yield is obtained by boiling benzoic acid with three times its weight of acetic anhydride and distilling the mixture.[13]

Numerous patents have appeared in which benzoic anhydride has been prepared: by the action of benzenesulfochloride upon

[2] Ann. **87**, 73 (1853).
[3] Ann. **128**, 127 (1863).
[4] Ann. **226**, 5 (1884).
[5] Gazz. Chim. Ital. **20**, 655 (1890).
[6] Ber. **17**, 1282 (1884).
[7] Ann. **226**, 15 (1884).
[8] Jahresb. **1854**, 409.
[9] Jahresb. **1856**, 464.
[10] D. R. P. 6,685; Frdl. **1**, 24 (1877–87).
[11] Gazz. Chim. Ital. **22**, 215 (1892); J. prakt. Chem. (2) **50**, 479 (1894).
[12] Ann. **226**, 12 (1884).
[13] Ber. **34**, 184 (1901).

sodium benzoate;[14] by the action of chlorosulfonic acid upon potassium benzoate;[15] by the action of silicon tetrachloride upon sodium benzoate;[16] by the action of sulfuryl chloride upon a mixture of calcium benzoate and sodium sulfate or sodium chloride;[17] by the action of sulfuryl chloride upon a mixture of 2 mols. of sodium benzoate and 1 mol. of calcium benzoate;[18] by the action of sulfur dioxide and chlorine upon sodium benzoate;[19] by the action of sulfuric anhydride upon a mixture of benzoic acid and sodium benzoate;[20] by the action of a mixture of sulfuric anhydride and carbon tetrachloride on sodium benzoate.[21]

It is probable that some of these patented processes would be more suitable for the commercial preparation of benzoic anhydride, but the method given in the procedure is satisfactory for the laboratory.

[14] D. R. P. 123,052; Frdl. **6**, 35 (1900–02).
[15] D. R. P. 146,690; Frdl. **7**, 28 (1902–04).
[16] D. R. P. 171,146; Frdl. **8**, 69 (1905–07).
[17] D. R. P. 171,787; Frdl. **8**, 68 (1905–07).
[18] D. R. P. 161,882; Frdl. **8**, 66 (1905–07).
[19] D. R. P. 210,805; Frdl. **9**, 68 (1907–10).
[20] D. R. P. 286,872; Frdl. **12**, 77 (1914–16).
[21] D. R. P. 290,702; Frdl. **12**, 79 (1914–16).

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COIMBATORE

## VIII

# $\beta$-BROMOPROPIONIC ACID

$$CH_2OH \cdot CH_2 \cdot CN + 2HBr + H_2O \rightarrow CH_2Br \cdot CH_2 \cdot CO_2H + NH_4Br$$

Prepared by E. C. Kendall and B. McKenzie.
Checked by H. T. Clarke and M. R. Brethen.

### 1. Procedure

To 2000 cc. of 40 per cent hydrobromic acid (Note 1) in a 3-l. flask is added 317 g. of ethylene cyanohydrin (p. 57), and the mixture is boiled for two hours under a reflux condenser. The condenser is then arranged for downward distillation and a thermometer immersed in the reaction mixture; dilute hydrobromic acid is distilled off until the temperature in the flask reaches 121°, whereupon the receiver is changed and a fraction consisting of stronger hydrobromic acid is collected over the range 121–129°. When the temperature of the mixture reaches 129°, very little hydrobromic acid remains, and on cooling, the mass sets to an almost colorless solid. This is now dissolved in 2000 cc. of carbon tetrachloride (Note 2), and the ammonium bromide is filtered off and washed with 500 cc. more of the solvent; a thin aqueous layer is separated and 1500 cc. of the carbon tetrachloride distilled from the filtrate. On cooling, about 470 g. of $\beta$-bromopropionic acid crystallizes from the residue; on filtering off and drying, this melts at 62.5–63.5°. On further concentration, the mother liquor yields a second crop of $\beta$-bromopropionic acid, amounting to 60–70 g.

The aqueous layer separated from the main carbon tetrachloride solution is shaken out with 100 cc. of carbon tetrachloride, and thus yields about 10 g. of pure acid; when the dilute and the concentrated hydrobromic acid fractions are extracted in the same way, about 5 g. and 15 g. respectively of

β-bromopropionic acid are obtained. The total yield is 560–570 g. (82–83 per cent of the theoretical amount).

## 2. Notes

1. The 2 l. (2750 g.) of 40 per cent hydrobromic acid may advantageously be replaced by a corresponding quantity (1550 cc.) of *constant-boiling 48 per cent hydrobromic acid*, should this be available.

2. In no case should benzene be used in place of carbon tetrachloride, as it has been found impossible to separate this solvent from β-bromopropionic acid, even on repeated fractionation with an efficient column.

## 3. Other Methods of Preparation

The chief methods for the preparation of β-bromopropionic acid are the action of hydrobromic acid on acrylic acid,[1] on hydracrylic acid,[2] and on ethylene cyanohydrin;[3] the oxidation of β-bromopropionaldehyde[4] and of trimethylene bromohydrin[5] with nitric acid.

[1] Ann. **163**, 96 (1872); **342**, 127 (1905).
[2] Ber. **18**, 227 (1885).
[3] J. Am. Chem. Soc. **39**, 1466 (1917).
[4] J. prakt. Chem. (2) **42**, 384 (1890); Bull. soc. chim. (3) **9**, 388 (1893).
[5] Ber. **54B**, 3117 (1921).

# IX

## CATECHOL

### A. (*from Salicylaldehyde*)

$$C_6H_4(ONa) \cdot CHO + H_2O_2 \rightarrow C_6H_4(OH)_2 + HCO_2Na$$

Prepared by H. D. Dakin.
Checked by H. T. Clarke and E. R. Taylor.

### 1. Procedure

To a solution of 122 g. of pure salicylaldehyde (Note 1) in 1000 cc. of normal sodium hydroxide solution at room temperature, is added 1420 g. of 3 per cent hydrogen peroxide. The mixture darkens slightly in color and the temperature rises to 45–50°. The solution is allowed to stand for fifteen to twenty hours, whereupon a few drops of acetic acid are added in order to neutralize any excess alkali, and the solution evaporated to complete dryness on the water bath under reduced pressure.

The solid residue is finely crushed and warmed nearly to boiling with 500 cc. of toluene; the mixture is then poured on to the folded filter paper of an extraction apparatus (Vol. II, p. 49) and extracted with boiling toluene for five hours. The toluene is allowed to cool and is decanted from the catechol, which crystallizes out. The insoluble material is again ground up and extracted in the apparatus with the decanted toluene. The combined product, weighing 70–76 g., consists of light brown plates melting at 104°, and is thus pure enough for many purposes. A further 6–12 g. of catechol can be obtained on distilling off the bulk of the toluene from the mother liquor. In order to obtain an entirely pure product, the crude catechol should be distilled under reduced pressure, when it passes over entirely at 119–121°/10 mm. (or 113–115°/8 mm.), and the

distillate recrystallized from about five times its weight of toluene. In this way, colorless plates melting at 104–105° are obtained. Yield 76–80 g. (69–74 per cent of the theoretical amount).

## 2. Notes

1. A considerably lower yield is obtained (50 per cent or less) if technical salicylaldehyde (not purified through the bisulfite compound) be employed.

2. The above process is applicable to almost all hydroxyaldehydes in which the hydroxyl and carbonyl groups occupy ortho or para positions relatively to each other;[1] in the latter case derivatives of hydroquinone are produced. When the hydroxyl and carbonyl groups occupy the meta position with respect to each other, no reaction takes place, as is also the case with certain ortho and para compounds containing nitro groups and iodine atoms. *o*-Hydroxyacetophenone and *p*-hydroxyacetophenone are also capable of yielding catechol and hydroquinone respectively under the above conditions.

3. Catechol may also be produced from salicylaldehyde by the use of certain derivatives of hydrogen peroxide, such as persulfates or sodium peroxide, but the method is far less convenient.

B. (*from Guaiacol*)

$$CH_3O \cdot C_6H_4 \cdot OH + HBr \rightarrow C_6H_4(OH)_2 + CH_3Br$$

Prepared by H. T. CLARKE and E. R. TAYLOR.
Checked by C. S. MARVEL and W. B. KING.

## 1. Procedure

IN a 5-l. flask fitted with a stirrer, a thermometer reaching to the bottom, a fractionating column about 40 cm. long (Note 2), and a return inlet tube, are placed 912 g. of crystalline guaiacol and 1500 g. of 48 per cent hydrobromic acid. This apparatus is connected with a condenser, an automatic separator, and an absorption vessel, as shown in the diagram (Note 1). The

[1] Am. Chem. J. 42, 477 (1909).

mixture is gently heated, with continual stirring, at such a rate that the vapor at the head of the column maintains a temperature of 85–95°. The mixture of water and guaiacol which condenses passes through the automatic separator (Note 3), the guaiacol being returned to the reaction vessel and the water collected in the tap funnel, from which it is removed from time

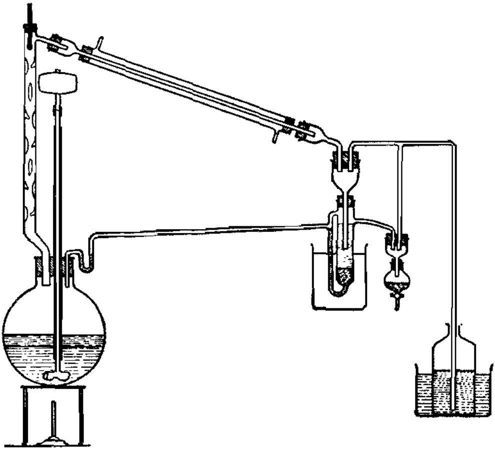


Fig. 1.

to time. The gaseous methyl bromide is collected in an ice-cooled bottle containing a weighed quantity (about 1600 g.) of methyl alcohol (Note 4).

After six to seven hours, the temperature at the head of the column begins to rise above 95° and finally reaches 98°, at which point practically no more guaiacol passes over with the distillate. This requires about one hour more, after which the heating is stopped (Note 5). The increase in weight of the absorption

bottle amounts to 400–500 g. (53–66 per cent of the theoretical amount of methyl bromide); the water collected weighs 550–560 g. (Note 6).

The residue in the flask, which has become pink in color, is extracted at 85–95° with three 1500-cc. portions of toluene, and the united extracts are distilled under reduced pressure on the steam bath until no more moisture passes over with the vapor. The solution (2–2.5 l.) is then allowed to cool, whereupon 385–390 g. of catechol separates in colorless plates melting at 104–105°. The mother liquor is further concentrated under reduced pressure and the residue finally distilled, pure catechol passing over at 124–125° 12 mm. The distillate, on recrystallization from a small quantity of toluene, yields 8–10 g. of pure material.

The aqueous residue from the three extractions with toluene yields, when the bulk of the water has been distilled off on the steam bath under reduced pressure, a further quantity of catechol by extraction with hot toluene, but the crystals so obtained are contaminated with a red impurity. It is therefore preferable to distil the entire residue, again collecting the fraction boiling at 124–125° 12 mm. and recrystallizing it from fresh toluene. In this way 295–305 g. of pure product is obtained. The forerun contains a little aqueous hydrobromic acid, which may be employed in a subsequent batch. The total yield of pure catechol is 690–705 g. (77–80 per cent of the theoretical amount).

## 2. Notes

1. In the diagram (Fig. 1) no indication is made of joints in the glass tubing. These are, however, applicable at almost any desired point; but care should be taken to arrange them so that the ends of the glass tube come into contact, since methyl bromide appears to pass readily through the walls of the india rubber tubing. It is necessary to make certain that the outlets from the automatic separator descend in an even incline and that the tubing itself is of sufficiently large diameter to prevent any siphoning effects.

2. Any column of standard form is suitable; to work satisfactorily, it is unnecessary for it to be more than 40 cm. in length.

3. It is noteworthy that the guaiacol which condenses is saturated with methyl bromide at the condensation temperature, so that it is necessary to prevent it from becoming warmer during its passage through the separator; otherwise the evolution of gas may hinder the ready formation of layers.

4. In order to secure satisfactory absorption of the methyl bromide, the methyl alcohol should be kept below 5° by ice-cooling.

5. Since the formation of the red by-product appears to depend upon the time during which the catechol is heated with hydrobromic acid, it is well to carry out the reaction as rapidly as possible; due care must be taken, however, that the temperature at the head of the column does not rise prematurely above 95°.

6. The water collected during the reaction contains practically no hydrobromic acid but is saturated with guaiacol and methyl bromide. Nevertheless, it scarcely pays to recover the dissolved compounds, for on distillation only 1-2 g. of wet guaiacol can be collected; while the value of the methyl bromide is in any case not very great.

7. The reaction appears to be applicable to many other cases where the constitution of the molecule permits of boiling with strong hydrobromic acid.

## 3. Other Methods of Preparation

The general reaction upon which the first of the above two methods is based is that described by Dakin in 1909;[2] the demethylation of guaiacol to catechol has been effected by heating with aluminum chloride[3] and with hydriodic acid.[4] Other important methods of preparation consist in treating ortho halogen-substituted phenols with alkalies under suitable

[2] Am. Chem. J. **42**, 477 (1909).
[3] Ber. **25**, 3532 (1892); D. R. P. 70,718, Frdl. **3**, 52 (1890–94).
[4] Ber. **8**, 153 (1875); J. Chem. Soc. **57**, 587 (1890).

conditions;[5] replacement of sulfonic groups[6] or amino groups[7] by hydroxyl; and oxidation of phenol[8] or benzene[9] by means of hydrogen peroxide. The majority of these, however, are unsuitable as laboratory methods.

[5] Ann. **120**, 315 (1861); Z. **1868**, 322; D. R. P. 84, 828, Frdl. **4**, 114 (1894–97); D. R. P. 249,939, Frdl. **10**, 1330 (1910–12); D. R. P. 269,544, Frdl. **11**, 190 (1912–14); Cf. Ber. **8**, 363 (1875).

[6] Z. **1867**, 643; D. R. P. 80,817, Frdl. **4**, 116 (1894–97); D. R. P. 81,209, Frdl. **4**, 117 (1894–97).

[7] Ber. **30**, 2568 (1897); D. R. P. 167,211, Frdl. **8**, 128 (1905–07).

[8] Bull soc. chim. (2) **43**, 157 (1885).

[9] Ber. **33**, 2017 (1900).

## X

## $o$-CHLOROTOLUENE AND $p$-CHLOROTOLUENE

$$CH_3 \cdot C_6H_4 \cdot NH_2 + HNO_2 + HCl \rightarrow CH_3 \cdot C_6H_4 \cdot N_2Cl + 2H_2O$$
$$CH_3 \cdot C_6H_4 \cdot N_2Cl + CuCl \rightarrow CH_3 \cdot C_6H_4 \cdot Cl + N_2 + CuCl$$

Prepared by C. S. MARVEL and S. M. MCELVAIN.
Checked by OLIVER KAMM.

### 1. Procedure

A. *Preparation of the cuprous chloride solution.* A solution of 1250 g. (5 mols.) of crystallized copper sulfate and 325 g. (5.6 mols.) of sodium chloride in 4 l. of hot water is prepared in a 12-l. flask. The flask is fitted with a mechanical stirrer, and an alkaline solution of sodium sulfite (265 g. of sodium bisulfite and 175 g. of sodium hydroxide in 2 l. of water) is added during a period of five to ten minutes. The mixture is allowed to cool to room temperature and washed by decantation. The cuprous chloride is obtained as a white powder, which, however, darkens on exposure to the air. The crude product is dissolved in 2 kg. of commercial 28 per cent hydrochloric acid (sp. gr. 1.14) and the solution is used in the following preparation.

B. *Preparation of chlorotoluene.* In a 10-l. stone jar fitted with a mechanical stirrer are placed 2 kg. of commercial 28 per cent hydrochloric acid (sp. gr. 1.14) and 428 g. (4 mols.) of $o$-toluidine. The mixture is cooled to 0° by adding cracked ice (about 1 kg. is required). The $o$-toluidine hydrochloride separates as a finely divided precipitate. The stirrer is started, and to the cold suspension is added a solution of 280 g. (4.05 mols.) of sodium nitrite in 800 cc. of water; the diazotization is carried out at 0–5° and requires about fifteen minutes. Cracked ice is added from time to time to keep the temperature within the proper limits. The volume of the final solution is 5–6 l.

While the diazotization is being carried out the cuprous chloride solution is cooled to 0°. The cold diazonium solution is now poured rapidly into the well-stirred cuprous chloride solution. The solution becomes very thick, owing to the separation of an addition product between the diazonium salt and the cuprous chloride. The cold mixture is allowed to warm up to room temperature, and stirring is continued for two and a half to three hours at this temperature (Note 3). When the temperature reaches about 15°, the solid addition compound begins to break down with the formation of nitrogen and *o*-chlorotoluene. After the specified time the solution is placed on a steam bath and heated to 60° to complete the decomposition of the addition product. The *o*-chlorotoluene forms a layer on top of the copper salt solution. The water solution is drawn off through a siphon until only 5–6 l. remains. The remaining material is steam-distilled from a 12-l. round-bottom flask (Note 4) until about 3.5–4 l. is collected in the distillate. The *o*-chlorotoluene layer is separated from the water, washed with cold concentrated sulfuric acid (Note 5), then with water, and is finally dried over calcium chloride. The product boiling at 155–158° weighs 375–400 g. (74–79 per cent of the theoretical amount).

*p*-Chlorotoluene is prepared in exactly the same way starting with *p*-toluidine. The yields are 70–79 per cent of the theoretical amount of a product which boils at 158–162° and melts at 4–7°.

## 2. Notes

1. The cuprous chloride solution prepared as described above is more satisfactory and cheaper than one prepared by reducing cupric chloride with copper turnings.

2. If less cuprous chloride is used the yield is lowered. It seems desirable to use 1 mol. of cuprous chloride (CuCl) to 1 mol. of diazonium salt. Increasing the amount of cuprous chloride beyond this point does not improve the yield.

3. The literature directions usually call for mixing the diazonium solution and the cuprous chloride solution at about 30–40°. This procedure gives a yield considerably lower than

that obtained by mixing the solutions cold and allowing to warm up gradually. If the mixture obtained by adding the diazonium solution to the cuprous chloride solution is heated at once, the yield falls to 55–65 per cent.

4. The steam distillation can be conveniently carried out in the apparatus used in the steam distillation of quinoline (Vol. II, p. 80).

5. The treatment with sulfuric acid is necessary to remove cresol and a trace of azo compound that usually colors the crude product and cannot be removed by distillation.

### 3. Other Methods of Preparation

*o*-Chlorotoluene has been obtained by the action of chlorine on toluene in the presence of various catalysts;[1] by the action of sulfuryl chloride on toluene in the presence of aluminum chloride;[2] by the chlorination of *p*-toluenesulfochloride followed by hydrolysis;[3] by the diazotization of *o*-toluidine followed by replacement of the diazonium salt group by chlorine.[4]

*p*-Chlorotoluene has been obtained by the action of chlorine on toluene in the presence of various catalysts;[5] by the action of sulfuryl chloride on toluene in the presence of aluminum chloride;[6] by the electrolytic reduction of *p*-chlorobenzaldehyde;[7] by the diazotization of *p*-toluidine followed by replacement of the diazonium salt group with chlorine.[8]

[1] Ber. **6**, 790 (1873); Ann. **237**, 152 (1887); Compt. rend. **135**, 1121 (1902).

[2] Rec. trav. chim. **30**, 387 (1911).

[3] D. R. P. 133,000; Chem. Zentr. **1902** (2), 313; D. R. P. 294,638; C. A. **11**, 2582 (1917).

[4] Ann. **247**, 367 (1888); **269**, 394 (1892); **272**, 145 (1893); Ber. **18**, 1939 (1885); **23**, 1221 (1890); **44**, 254 (1911); Z. physik. Chem. **4**, 71 (1889); Z. angew. Chem. **23**, 392 (1910).

[5] Ann. **139**, 334 (1866); **237**, 152 (1887); Ber. **6**, 790 (1873); **8**, 1402 (1875).

[6] Ber. **26**, 2941 (1893); Rec. trav. chim. **30**, 387 (1911).

[7] J. Chem. Soc. **99**, 1114 (1911).

[8] Ber. **6**, 794 (1873); **18**, 1939 (1885); **23**, 1221 (1890); **44**, 254 (1911); Z. angew. Chem. **23**, 392 (1910).

## XI

## *p*-CRESOL

$$CH_3 \cdot C_6H_4 \cdot SO_3Na + KOH \rightarrow CH_3 \cdot C_6H_4 \cdot OH + KNaSO_3$$

Prepared by W. W. Hartman.
Checked by Roger Adams and A. W. Sloan.

### 1. Procedure

One kg. of technical sodium hydroxide and 400 g. of technical potassium hydroxide (Note 2) are melted together in a cast-iron flat-bottom kettle, 18 cm. in depth and 18 cm. in diameter. The fused mass is well stirred by means of a piece of iron pipe closed at one end, containing a thermometer; the hand is protected by an india rubber glove wrapped with a cloth. The temperature of the fused mass is allowed to fall to 230°, and 150 g. of technical sodium *p*-toluenesulfonate is stirred in. The temperature is now slowly raised while 450 g. more of sodium *p*-toluenesulfonate is added slowly, the additions being made whenever the melt becomes sufficiently thin to stir in the solid. When all has been added, the temperature should be about 270°; the addition requires about thirty minutes. The temperature is now raised to 300°, with occasional stirring. At this point there is a layer of heavy froth on the surface of the thin melt, and as the temperature rises this is stirred in, the whole melt becoming frothy and showing a tendency to foam over. On continuing to raise the temperature, the foaming suddenly disappears at about 330°; the melt becomes dark and evolution of hydrogen sets in. The mixture is now thin and of uniform consistency; it is poured at once into an iron tray and allowed to cool.

The solidified product is dissolved in 6–7 l. of water in a 12-l. flask, and a solution of concentrated (95 per cent) sulfuric

acid (about 880 cc.) in about 2 l. of water is added until the liquor has a distinct odor of sulfurous acid. The heat of neutralization is sufficient to cause the solution to boil; it is at once distilled in a current of steam (Note 3) until a sample of the distillate gives only a slight precipitate with bromine water. The distillate (about 6–7 l.) is saturated with salt and the oil separated. *The watery solution may be again distilled with* steam in order to recover the small amount of cresol in solution. The oil is at once distilled under reduced pressure, and the fraction which boils at 95–96°/15 mm. is collected. The forerun is freed of water and redistilled, yielding a further quantity. On cooling, the product solidifies to a white, crystalline mass melting at 31°. The yield is 200–230 g. (60–70 per cent of the theoretical amount).

## 2. Notes

1. Technical sodium *p*-toluenesulfonate is, as a rule, of about 95 per cent purity; it contains about 2 per cent of sodium chloride and some moisture. Attempts to prepare a *p*-cresol of *higher melting point by fusion of recrystallized sodium p-toluene*-sulfonate (which should presumably contain no isomers) have failed; it has been found impossible to raise the melting point above 31.4°.

2. Fusion with sodium hydroxide alone yields no cresol, the fused sodium hydroxide appearing to have no solvent action on the sodium *p*-toluenesulfonate. On the other hand, potassium hydroxide works entirely satisfactorily, as do mixtures of sodium hydroxide and potassium hydroxide containing not less than 28 per cent of potassium hydroxide. In the above directions the minimum amount of potassium hydroxide is indicated.

3. Since distillation in a current of steam in a laboratory is apt to be a tedious process when only the regular form of Liebig condenser is employed, much time can be saved by the use of the apparatus described in Vol. II, p. 80.

### 3. Other Methods of Preparation

The only other important method by which *p*-cresol can be prepared is decomposition of diazotized *p*-toluidine;[1] the yield is not very good, however, and the quality of the product is almost always poor. The literature also contains methods for its formation from *p*-toluenesulfonic acid by fusion with potassium hydroxide.[2]

[1] Jahresb. **1866**, 458; Z. **1868**, 325.
[2] Ann. **144**, 122 (1867); **156**, 258 (1870); Z. **1869**, 618.

# XII

## 9,10-DIBROMOANTHRACENE

$$C_{14}H_{10} + 2Br_2 \rightarrow C_{14}H_8Br_2 + 2HBr$$

Prepared by I. M. HEILBRON and J. S. HEATON.
Checked by H. T. CLARKE and T. F. MURRAY.

### 1. Procedure

To a suspension of 300 g. of anthracene of 80–85 per cent purity in 3 l. of carbon tetrachloride, in a 5-l. flask fitted with dropping funnel, stirrer, and reflux condenser, is added slowly 567 g. of *bromine. The bromination takes place in the cold* with separation of the sparingly soluble 9,10-dibromoanthracene; in order to prevent undissolved anthracene from becoming coated over, it is necessary to maintain vigorous stirring throughout the reaction. A tube from the top of the condenser conducts hydrogen bromide to cold water, in which it is absorbed. The addition of the bromine occupies about half an hour; the rate is so adjusted that a minimum of bromine is carried over with the hydrogen bromide.

When all the bromine has been added, the mixture is gently warmed on a steam bath with continual stirring, care being taken not to heat so rapidly as to cause undue loss of bromine by entrainment. Heating is continued until the mixture has boiled gently for an hour. The mixture is then allowed to cool for some hours, without stirring, and the crude dibromoanthracene is filtered off, washed with a little cold carbon tetrachloride, and dried. In this way 270–425 g. of a bright yellow product, which melts (Note 4) at 218–219° (corr.), is obtained. On concentrating the mother liquors, 15–150 g. more of crude material (m. p. about 216° corr.) can be obtained.

To prepare an absolutely pure product, the crude dibromo-

anthracene is extracted with carbon tetrachloride (Note 2) in an apparatus similar to that described in Vol. II, p. 49; the extraction is carried to the point at which crystals just begin to separate from the boiling solvent, and a fresh quantity of carbon tetrachloride is then taken. About eight extractions are necessary, 1 l. being used each time. The 9,10-dibromoanthracene so purified consists of brilliant yellow needles melting at 221–222° (corr.). A further quantity of pure product may be obtained by concentrating the mother liquor and recrystallizing the second crop so obtained. The recovered solvent may be employed for further extractions. The yield amounts to 400–420 g. (83–88 per cent of the theoretical quantity based on anthracene of 85 per cent purity).

## 2. Notes

1. The reaction may be carried out equally well with a larger proportion of solvent, but if less than the amount indicated be taken, difficulty may arise in stirring. Carbon bisulfide may be employed instead of carbon tetrachloride, but this solvent presents no essential advantages and it is necessary to use a larger volume for the same amount of anthracene.

2. The crude product may be recrystallized from toluene, in which it is somewhat more soluble than in carbon tetrachloride; the color of the product is, however, not quite so light, although the melting point is as high as if carbon tetrachloride were used. If desired, recrystallization may be effected from toluene without using the extraction apparatus, in which case about 10 l. of solvent in all will be required; for the filtration of the hot solution, a plug of glass wool, previously wetted with boiling xylene, may be employed, care being taken to warm the funnel adequately.

3. The bromination products of the impurities with which commercial anthracene is contaminated appear to be more soluble in carbon tetrachloride than in 9,10-dibromoanthracene; the yield can be slightly increased by fractional recrystallization of the products contained in the original mother liquor, but

under laboratory conditions the gain does not compensate for the time involved.

4. The observed melting-points of the various products are 5–6° lower than the corrected values.

5. The watery solution of hydrogen bromide, on fractional distillation, readily yields 48 per cent hydrobromic acid, boiling at 125–126°/760 mm. (cf. Vol. I, p. 2).

### 3. Other Methods of Preparation

The only preparative method to be found in the literature [1] consists in the bromination of anthracene in dilute carbon disulfide solution.

[1] Ann. Suppl. 7, 275 (1870).

## XIII

# DIPHENYLACETIC ACID

$$(C_6H_5)_2C(OH) \cdot CO_2H + 2H \rightarrow (C_6H_5)_2CH \cdot CO_2H + H_2O$$

Prepared by C. S. MARVEL, F. D. HAGER and E. C. CAUDLE.
Checked by J. B. CONANT and A. W. SLOAN.

## 1. Procedure

IN a 1-l. round-bottom flask are placed 250 cc. of glacial acetic acid, 15 g. of red phosphorus and 5 g. of iodine. The mixture is allowed to stand for fifteen to twenty minutes until the iodine has reacted, and then 5 cc. of water and 100 g. of benzilic acid are added. A reflux condenser is attached and the mixture is boiled continuously for at least two and a half hours. After the reaction is complete, the hot mixture is filtered with suction to remove the excess red phosphorus (Note 2). The hot filtrate is slowly poured into a cold, well-stirred, filtered solution of 20–25 g. of sodium bisulfite in 1 l. of water (Note 3). This procedure removes the excess iodine and precipitates the diphenylacetic acid as a fine white or slightly yellow powder (Note 4). The product is filtered with suction, washed with cold water and dried thoroughly on filter paper. The yield is 88–90 g. (94–97 per cent of the theoretical amount) of a solid melting at 141–144° (Note 5). If a crystalline product is desired, the acid is dissolved in about 500 cc. of hot 50 per cent alcohol and then cooled. The melting point after recrystallization is 144–145°.

## 2. Notes

1. In place of phosphorus, iodine and water, a dilute solution of hydriodic acid and phosphorus may be used.

2. If difficulties are encountered in filtering the hot acetic acid solution through filter paper, an asbestos filter may be prepared and used to advantage.

3. Some samples of sodium bisulfite caused part of the diphenylacetic acid to dissolve. This can always be avoided if, after the solution of sodium bisulfite is prepared, a current of sulfur dioxide is passed in, until the solution is acid to litmus.

4. Sometimes, if the acetic acid solution is poured into the water too rapidly, the product will be slightly pink and a reprecipitation from acetic acid solution will be necessary.

5. The melting points of benzilic acid and diphenylacetic acid lie very close together. However, it is very easy to test for complete reduction by treating a little of the product with cold concentrated sulfuric acid. If even a trace of benzilic acid remains the sulfuric acid will turn red.

### 3. Other Methods of Preparation

Diphenylacetic acid has been obtained by the reduction of benzilic acid with hydriodic acid and red phosphorus;[1] by the treatment of phenylbromoacetic acid with benzene and zinc dust,[2] or with benzene and aluminum chloride;[3] by the hydrolysis of diphenylacetonitrile;[4] by heating $\alpha$-diphenyldichloroethylene with alcoholic sodium ethylate;[5] by heating benzilic acid;[6] from diphenylmethane, mercury diethyl, sodium and carbon dioxide;[7] by the oxidation of $\alpha,\alpha,\delta,\delta$-tetraphenyl-$\beta$-butine;[8] by the decomposition of some complex derivatives obtained from diphenylketene;[9] by the hydrolysis of diphenyl-5,5-hydantoin;[10] by the treatment of diphenylbromoacetic acid with copper;[11] by the oxidation of dichlorodiphenylcrotonic acid.[12]

[1] Ann. **155**, 84 (1870); **275**, 84 (1893); Ber. **24**, 3556 (1891); **44**, 442 (1911).
[2] Ann. **171**, 122 (1874).
[3] Chem. Weekblad **5**, 655 (1908).
[4] Bull. soc. chim. (2), **33**, 590 (1880); Ann. **233**, 349 (1886).
[5] Ann. **306**, 81 (1899).
[6] Ann. **298**, 242 (1897); Ber. **40**, 4060 (1907).
[7] Ber. **43**, 1942 (1910).
[8] Z. Electrochem. **16**, 671 (1910).
[9] Ber. **42**, 4261 (1909); **44**, 523, 531 (1911).
[10] Ber. **46**, 139 (1913).
[11] Ann. **396**, 262, footnote 1 (1913).
[12] Am. Chem. J. **19**, 644 (1897).

# XIV

## EPICHLOROHYDRIN

$$CH_2Cl \cdot CHOH \cdot CH_2Cl + NaOH \rightarrow$$
$$H_2O + (CH_2Cl \cdot CHONa \cdot CH_2Cl) \rightarrow CH_2Cl \cdot \overbrace{CH - CH_2}^{O} + NaCl$$

Prepared by H. T. Clarke and W. W. Hartman.
Checked by Roger Adams and H. O. Calvery.

### 1. Procedure

In a 5-l. flask (Note 1) provided with a mechanical stirrer, a reflux condenser, and a hopper which can be opened or closed at the bottom by means of a rubber bung attached to a glass rod

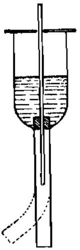


Fig. 2.

(Fig. 2), are placed 3 l. of anhydrous ether and 1290 g. of glycerol α,γ-dichlorohydrin (Vol. II, p. 29). The flask is surrounded by a cold water bath, and 440 g. of finely powdered sodium hydroxide (Note 2), which has been passed through a 20-mesh sieve, is added in small portions, with continual stirring, while the temperature is kept at 25–30°. The addition requires about

twenty minutes. The cold water is replaced by water at 40–45°, and the mixture boiled gently with stirring for four hours. It is necessary to cool the vessel at least once every hour during this period and break up with a rod or wire (Note 3) any lumps which cling to the side of the flask and are not incorporated by the stirrer.

The mixture is finally cooled and the ethereal solution carefully decanted from the solid, which is carefully rinsed twice with 250 cc. portions of dry ether. The united liquids are then distilled from a water bath held at 40–60°, the residue is fractionated with a column, and the fractions boiling at the following points are collected: up to 110°; at 110–115°; at 115–117°; and at 117–140°. The portion boiling at 115–117° is pure epichlorohydrin; the lower and higher fractions are systematically redistilled, yielding a further quantity of pure material. The yield is 705–747 g. (76–81 per cent of the theoretical amount). The residue, varying from 16 to 150 g., consists of nearly pure glycerol dichlorohydrin, and may be employed in subsequent runs (Note 4).

## 2. Notes

1. A flask fitted with three necks (Vol. I, p. 12) is very satisfactory for this reaction; if it be not available, the tubes leading from the reflux condenser and the hopper must be bent at slight angles to prevent congestion of apparatus.

2. The principal difficulties in the preparation are connected with the use of finely powdered alkali. Care must be taken to expose the powder as little as possible to a moist atmosphere, for if it becomes at all damp it tends to clump together and difficulty is experienced in adding it to the mixture. For this reason, and also on account of the irritating action of alkali on the mucous membranes, the sieve should be provided with well-fitting cover and receiver; the sifted material should be weighed out into a stoppered bottle and placed in the apparatus directly from this container. The hopper from which the alkali is added to the mixture should be covered with a card with a hole through

which the rod passes. The bung on the rod may conveniently be constructed from a rubber stopper of appropriate size.

3. As stated by Claus,[1] the action of alkalies, whether solid or in aqueous or alcoholic solution, causes the formation of a considerable proportion of glycerol. This by-product, although formed to a markedly less extent when the reaction is carried out in ether, tends to coagulate the alkali and salt, so that it is essential to loosen the mass occasionally by poking it with a rod. Ether was selected as a diluent since it was hoped that in a non-hydroxylic medium the first stage of the reaction—replacement of hydrogen by sodium—would take place to a greater extent than if water or other hydroxylic liquid, such as alcohol or the dichlorohydrin itself, were employed. This is probably the case, since Claus found in an extensive series of experiments that the yield never rose above 42 per cent of that theoretically possible, even when solid alkali was employed without a diluent.

4. It is not essential to redistil the recovered dichlorohydrin, since the glycerol which forms the principal by-product is retained by the excess alkali and does not enter the ether.

### 3. Other Methods of Preparation

The only methods which come into consideration depend upon the action of alkalies upon glycerol $\alpha$- or $\beta$-dichlorohydrins.[1, 2]

[1] Ber. **10**, 557 (1877).
[2] Ann. Suppl. **1**, 221 (1861); Z. **1871**, 252; J. prakt. Chem. (2) **12**, 160 (1875).

## XV

## ETHYL β-BROMOPROPIONATE

$$CH_2Br \cdot CH_2 \cdot CO_2H + C_2H_5OH \rightarrow CH_2Br \cdot CH_2 \cdot CO_2C_2H_5 + H_2O$$

Prepared by E. C. KENDALL and B. MCKENZIE.
Checked by H. T. CLARKE and M. R. BRETHEN.

### 1. Procedure

To the crude mixture of ammonium bromide and β-bromopropionic acid, prepared as described on p. 25, from 317 g. of ethylene cyanohydrin, are added 1200 cc. of carbon tetrachloride and 200 cc. of the same solvent which has been shaken with the aqueous distillates; the ammonium bromide is filtered off and washed with 200 cc. of carbon tetrachloride. The watery layer, amounting to about 350 cc., is separated and shaken with 100 cc. of carbon tetrachloride. To the united carbon tetrachloride solutions are added 450 cc. of 95 per cent ethyl alcohol and 10 g. of sulfosalicylic acid or phenolsulfonic acid to act as a catalyst (Note 1).

The mixture is now boiled in a 3-l. flask, the vapors being passed through an efficient condenser and the condensed liquid run into an automatic separator (see Vol. I, p. 68) so arranged that the heavy liquid is returned to the flask and the lighter aqueous liquid discarded. If the boiling is sufficiently vigorous no more water will separate after two to two and a half hours' boiling (Note 2). The reaction mixture is now cooled, washed with dilute sodium carbonate solution, and distilled with the use of a column until the temperature of the vapor reaches 85° and that of the liquid in the flask about 115°. The residue is then transferred to a flask provided with a column for distillation under reduced pressure (see Vol. I, p. 30) and distilled. The fraction boiling at 60–65°/15 mm. is collected, 690–700 g. of

pure ethyl β-bromopropionate being obtained (85–87 per cent of the theoretical amount). A high-boiling residue, probably consisting of ethyl hydracrylate, remains in the flask, but the amount is practically negligible.

## 2. Notes

1. The esterification may be carried out without the addition of a sulfonic acid, as traces of hydrobromic acid generally remain in the crude material; but since the time of operation must be kept as short as possible this omission is not recommended. It has been found that if the water be not removed and the mixture boiled under a reflux condenser for two hours before the distillate is passed through the automatic separator, the yield falls to 70–75 per cent of the theoretical amount.

2. It is important to carry out the esterification as rapidly as possible in order to cut down to a minimum the formation of ethyl hydracrylate, which takes place by the action of water on the β-bromopropionic acid or ester; an efficient condenser is therefore necessary. For the same reason it is necessary to remove all residual water from the mixture before adding the alcohol.

3. As in the preparation of the β-bromopropionic acid, benzene must not be substituted for the carbon tetrachloride, as it has been found impossible to make a satisfactory separation of this solvent from the ester.

## 3. Other Methods of Preparation

Ethyl β-bromopropionate has always been prepared by the esterification of β-bromopropionic acid.[1]

[1] J. prakt. Chem. (2) **42**, 384 (1890); Compt. rend. **118**, 1268 (1894).

## XVI

## ETHYL CYANOACETATE

$$Cl \cdot CH_2 \cdot CO_2Na + NaCN \rightarrow CN \cdot CH_2 \cdot CO_2Na + NaCl$$
$$CN \cdot CH_2 \cdot CO_2H + C_2H_5OH \rightarrow CN \cdot CH_2 \cdot CO_2C_2H_5 + H_2O$$

Prepared by E. P. KOHLER and C. F. H. ALLEN.
Checked by C. S. MARVEL and H. O. CALVERY.

### 1. Procedure

A mixture of 625 g.of chloroacetic acid and 940 g. of cracked ice in a large battery jar is accurately neutralized to litmus with a cold solution of sodium hydroxide containing 333 g. per l.; about 825 cc. is required. The temperature must not be allowed to rise above 30° during the neutralization.

A solution is now made (in the hood) of 387.5 g. of sodium cyanide (1.174 mol.) in 780 cc. of water. This is heated, gently at first to induce rapid solution, and finally to boiling. To the hot solution is added 300 cc. of the sodium chloroacetate solution, and the flame is removed as soon as the action begins. When the vigorous reaction has subsided somewhat, another 300-cc. portion is added; this is continued until all has been added. The mixture is then boiled for five minutes, and finally cooled under the tap for half an hour (Note 1).

To the solution (in the hood) is added slowly, with stirring, 767 cc. of 43 per cent sulfuric acid (sp. gr. 1.333), or its equivalent of about this concentration. Some hydrogen cyanide is evolved from the excess cyanide present. The volume is now 4400 cc. The mixture is left to stand for five minutes to allow any salts to precipitate, and filtered in a centrifuge or by suction, the salt being saved for future use. The aqueous solution is evaporated under diminished pressure, using a 2-l. Pyrex distilling flask fitted with a dropping funnel and a capillary tube for

admitting air below the surface of the liquid. The receiver consists of two 1-l. suction flasks in series in an ice bath. The distilling flask is immersed in a hot-water bath, the temperature of which is not allowed to rise above 80° (Note 2); 500 cc. of the solution is put in the flask and distillation commenced, the remainder of the solution being added from the dropping funnel as fast as it will distil. The flask should be shaken if bumping occurs on account of the separated salt. Heating is continued until no more distillate is obtained; the time required amounts to about eight hours.

While the distillation is proceeding the salt is washed in the centrifuge or on the funnel with 95 per cent ethyl alcohol, first with two 100-cc. portions and finally with one of 200 cc. The salt is discarded, and the filtrate added to the residue in the distilling flask while it is still warm, the whole being shaken to prevent a solid cake from forming. After it has been thoroughly shaken in order to break up any lumps, the salt in the distilling flask is filtered off or centrifuged and washed as before, twice with 100-cc. portions of 95 per cent ethyl alcohol and finally with one of 280 cc. The salt, which should he nearly dry, is discarded; the alcoholic filtrate is distilled under reduced pressure from a water bath held at 60° (Note 2), continuing as long as any liquid comes over (about three hours). Alcohol may be recovered from the distillate.

The residual liquid is carefully decanted from any salt into a 2-l. round-bottom flask, and rinsed carefully with 300 cc. of absolute ethyl alcohol. The cyanoacetic acid so obtained is esterified by passing the vapor of ethyl alcohol into the hot solution. The apparatus for esterification is arranged as follows: a rubber stopper to fit the 2-l. flask containing the acid is bored for (*a*) a fractionating column connected with a condenser set for downward distillation, (*b*) a thermometer, the bulb of which dips into the liquid, (*c*) a glass tube reaching to the bottom of the flask, drawn out into a large capillary. A 1-l. Pyrex round-bottom flask is fitted with a stopper carrying (*a*) a dropping funnel, (*b*) a safety tube (to release pressure, if necessary), and (*c*) a bent glass tube to conduct the alcohol vapor through a

trap to the capillary glass tube in the reaction flask. The purpose of the trap is to catch any liquid that may be sucked back from the reaction flask.

To the reaction mixture is added 15 cc. of concentrated sulfuric acid and the flask is placed in an oil bath; connections are made to the rest of the apparatus and heating is commenced. About 70 cc. of alcohol will distil over before the temperature of the mixture reaches 110°. Meanwhile, 600 cc. of 95 per cent ethyl alcohol is placed in the 1-l. flask. As soon as the temperature reaches 110° this alcohol is boiled so that a rapid stream of vapor passes into the reaction mixture—the temperature should remain at 110°. More alcohol is added to that in the 1-l. flask until 800 cc. has been added; heating is continued until all has been vaporized, whereupon the safety tube is opened at once. The flask is removed from the oil bath and allowed to cool. This esterification takes about three hours. The distillate obtained during the process consists of dilute alcohol.

When the ester has cooled to room temperature, the sulfuric acid is neutralized with a strong solution of sodium carbonate; the ester (upper layer) is separated, and the aqueous solution extracted with ether, or preferably benzene; about one-tenth of the yield is in the extract. The combined products are placed in a 1-l. vacuum distillation flask and distilled under reduced pressure, after the bulk of the solvent and accompanying alcohol and water has been removed. When the temperature of the distillate reaches 94°/16 mm. the receiver is changed, and the ester collected from 94° to 99°, most of it coming over at 97–98°/16 mm. (Note 3). The temperature of the oil bath should not rise above 145°. A small amount (about 60 g.) of residue remains in the flask. The yield is 490–550 g. (65–75 per cent of the theoretical amount). The total time necessary for the preparation of this quantity of ester is about twenty-four hours.

## 2. Notes

1. The reaction between sodium chloroacetate and sodium cyanide should take place quickly; the solution should not be boiled more than five minutes.

2. The solution containing mineral acid must not be evaporated at a high temperature, or ethyl malonate will be formed.

3. Ethyl cyanoacetate boils at 97°/16 mm., 101°/19 mm., 107°/27 mm. A very small amount of white solid sometimes appears in the distillate; this will settle out or may be filtered off.

4. Methyl cyanoacetate can also be made by this method, if methyl alcohol be used instead of ethyl alcohol.

### 3. Other Methods of Preparation

Ethyl cyanoacetate has been prepared by the action of potassium cyanide on ethyl chloroacetate,[1] and by the esterification of cyanoacetic acid.[2]

[1] Ann. **133**, 339 (1865); Jahresb. **1874**, 561; Bull. soc. chim. **46**, 62 (1886); J. Am. Chem. Soc. **26**, 1545 (1904); Proc. Chem. Soc. **30**, 307 (1914).

[2] Am. J. Sci. **26**, 267 (1908).

XVII

## ETHYLENE CYANOHYDRIN

$$CH_2OH \cdot CH_2Cl + NaCN \rightarrow CH_2OH \cdot CH_2 \cdot CN + NaCl$$

Prepared by E. C. KENDALL and B. MCKENZIE.
Checked by H. T. CLARKE and W. M. SPERRY.

### 1. Procedure

IN a 5-l. flask is placed 612 g. of finely powdered sodium cyanide (passed through a meat grinder and then sifted through a 20-mesh sieve); the flask is equipped with a thermometer in a well, an efficient stirrer, and a reflux condenser (Note 4). The whole vessel is then set in a water bath into which warm and cold water can be run at will and if necessary rapidly removed.

A mixture of 250 cc. of water and 1000 g. of pure ethylene chlorohydrin (b. p. 126–127°) is then added, the stirring is started, and the temperature of the mixture raised to 45° by external application of warm water. At this point the warm water is rapidly removed (Note 2) and the temperature of the contents of the flask carefully held at 45° by jacketing with water at a suitable temperature (33–35°). After the mixture has been held at 45° for an hour it is allowed to warm up to 48° by allowing the temperature of the water bath to rise two degrees. After an hour at 48° the temperature is raised to 50° and held at this point until the reaction is over; it is necessary to raise the temperature of the bath gradually, and the end of the reaction is noted when the bath temperature reaches 50°. A period of four and a half to five hours is necessary for this last stage.

Cold water is now placed in the water bath, while the stirrer is kept always in motion, and the temperature of the mixture is reduced to 20–22°. The mass is then filtered by suction and the sodium chloride sucked as dry as possible. This is then washed

with about 800 cc. of acetone in small quantities, the washings being collected separately, and then transferred to a flask from which the acetone and water are distilled off with the use of a short fractionating column until the temperature of the vapor reaches 90°. The residue in the flask is then cooled and again filtered from a further small quantity of sodium chloride which separates during the distillation, the filtrate being added to the main product.

This is then distilled under reduced pressure from an oil bath, and the fraction boiling at 107–109°/12 mm. (116–118°/20 mm.) is collected as pure material. The yield is 700–705 g. (79–80 per cent of the theoretical amount). There is practically no residue beyond a little salt; the foreruns consist of water, a small amount of unchanged ethylene chlorohydrin and some ethylene cyanohydrin.

## 2. Notes

1. The sodium cyanide should be finely powdered since it never completely enters into solution, and any lumps present would run the risk of becoming coated over with sodium chloride. For the same reason, the stirring must be vigorous throughout the operation.

2. It is most important that the temperature of the reaction mixture be not allowed to rise prematurely, since if it reaches 50° during the early stages the reaction velocity increases so rapidly that the contents are apt to boil out of the flask. For the same reason it appears necessary that a certain ratio between reacting mass and cooled surface be not exceeded. Runs of twice the above size have been carried out in a 5-l. flask without mishap, but temperature control was difficult and these conditions are extremely hazardous. A run of 4 kg. of ethylene chlorohydrin in a 12-l. flask was attempted, but rapidly went out of control.

3. When the reaction has been carried out exactly as described, the final product before distillation is very nearly colorless; if the temperature has been allowed to rise too high,

a brown color is produced and ammonia is formed, with corresponding loss of yield.

4. Under the correct conditions no appreciable amount of hydrogen cyanide escapes from the reflux condenser, but it is wise to carry out the reaction under a hood or to lead a tube from the top of the condenser into the open air.

### 3. Other Methods of Preparation

Ethylene cyanohydrin has been prepared by the action of ethylene oxide upon anhydrous hydrocyanic acid;[1] but the majority of methods described in the literature have involved the interaction of ethylene chlorohydrin and alkali cyanide. This has been effected in the absence of a solvent by heating to 100° in a closed vessel,[2] by boiling the reagents in 50 per cent aqueous-alcoholic solution,[3] by adding a concentrated aqueous solution of potassium or sodium cyanide to a boiling solution of ethylene chlorohydrin in absolute alcohol,[4] and in aqueous solution at 45°.[5]

[1] Ann. **191**, 270 (1878); *cf.* Ann. **167**, 346 (1873).

[2] Ann. **128**, 4 (1863).

[3] Ann. **191**, 268 (1878).

[4] Bull soc. chim. (3) **9**, 426 (1893); *ibid.* (4) **27**, 902 (1920); J. Am. Chem. Soc. **39**, 1465 (1917).

[5] U. S. Patent 1,388,016; C. A. **15**, 4011 (1921).

XVIII

## HYDROXYLAMINE HYDROCHLORIDE AND ACETOXIME

$$NaNO_2 + NaHSO_3 + SO_2 \rightarrow HON(SO_3Na)_2$$
$$HON(SO_3Na)_2 + CO(CH_3)_2 + H_2O \rightarrow HON{=}C(CH_3)_2 + 2NaHSO_4$$
$$HON{=}C(CH_3)_2 + HCl + H_2O \rightarrow HONH_2 \cdot HCl + CO(CH_3)_2$$

Prepared by WALDO L. SEMON.
Checked by H. T. CLARKE and ROSS PHILLIPS.

### 1. Procedure

IN a 2-gallon wide-mouth bottle packed in ice-salt mixture are placed 630 g. of commercial (95 per cent) sodium nitrite and 5 kg. of chopped ice, and the mixture is well stirred. A cold (0–5°) solution of sodium bisulfite, made by saturating with sulfur dioxide a solution of 495 g. of anhydrous sodium carbonate in 1500 cc. of water, is now added slowly with hand stirring. When all is in, a sufficiently large quantity of the ice will have melted to allow a mechanical stirrer to be fitted. A stream of sulfur dioxide is now passed in, with continual stirring, the temperature being kept at 0–2°, until an acid reaction to Congo red paper is obtained and the dark color, which appears just before the reaction is complete, has faded. During the addition of the sulfur dioxide, 500 g. more of ice may be added.

The mixture is now transferred to a 12-l. flask, 625 cc. (495 g.) of acetone is added, and the solution is heated on the steam bath to 70°. Heating is then discontinued, the flask wrapped in burlap in order to retard loss of heat, and the mixture allowed to stand over night. The acid is then neutralized with a concentrated (50 per cent) solution of sodium hydroxide (about 720 g. of alkali is required), a distinctly alkaline reaction to litmus being just obtained.

The resulting acetoxime is now distilled out in a current of steam (Note 2), and the distillation is continued until a 5-cc. sample, shaken out with 2 cc. of ether, yields no appreciable residue on evaporating the ether. To the distillate (2–2.5 l.) is added 600 cc. of concentrated hydrochloric acid, and the acid solution is distilled at atmospheric pressure until the distillate is free of acetone. The residual liquor is then evaporated to dryness on the steam bath, either in an open dish or preferably under reduced pressure; the crude hydroxylamine hydrochloride so obtained, weighing 296–470 g. (49–77 per cent of the theoretical amount) is suitable for many purposes, but is best purified by recrystallization from half its weight of water. By systematic recrystallization of the product from several batches, the yield of pure product, which crystallizes in long flat needles, melting when dry at 150–151°, may be brought as high as 70 per cent of the theoretical amount (Note 3).

In order to prepare pure acetoxime (Note 4), the procedure is modified in the following way: After neutralizing the solution of acetoxime formed after the addition of acetone, the oily layer is separated and the aqueous solution shaken with two or three 150-cc. portions of benzene. The oil and benzene solutions are mixed, the water thereby thrown ont is removed, and the oil fractionally distilled with the use of a column, the portion boiling 133–136° being collected as pure acetoxime. This product, which weighs 420–480 g., solidifies in the receiver to colorless needles melting at 60–61°. The foreruns and aqueous liquors are best distilled with steam and the distillate converted into hydroxylamine hydrochloride as above, whereupon 75–90 g. of pure salt is obtained.

## 2. Notes

1. The preparation can be run in larger batches than that indicated above. Earthenware crocks may suitably replace the glass bottle; but since the external cooling in such vessels is not so efficient, it will be necessary, in case they are used, to add a larger proportion of ice during the reaction in order to maintain the correct temperature. This, however, is of no great disadvan-

tage, since the formation of the oxime appears to take place equally well in more dilute solution. Metal cans are entirely satisfactory for the distillation of the faintly alkaline liquors.

2. The acetoxime may be distilled by direct heating rather than by injection of steam; when the prescribed quantities are taken, however, it will be found that the liquor becomes saturated with sodium sulfate at a point just before the expulsion of the oxime is complete, so that addition of water during the distillation is necessary. More rapid distillation can be obtained by the use of a current of steam, especially if a condensing receiver (Vol. II, pp. 80–82) be employed. The oxime can also, if desired, be isolated for hydrolysis by separation of the oily layer and extraction with benzene; the resulting crude hydroxylamine hydrochloride is, however apt to be dark in color and to contain inorganic salts.

3. The final mother liquors from the recrystallization of the hydroxylamine hydrochloride contain a high proportion of ammonium chloride. The hydroxylamine present therein is best recovered by reconversion into acetoxime, which is isolated by steam distillation of the faintly alkaline solution.

4. Acetoxime can be obtained in long needles by allowing the first portions of the steam distillate (which are saturated with oxime) to cool, and filtering off the crystals which separate; unfortunately, this product cannot be obtained in a perfectly dry condition without considerable loss by volatilization.

5. By redistillation of the aqueous acetone with the use of a column, 60 per cent or more of the material taken can readily be recovered and employed in a subsequent batch.

### 3. Other Methods of Preparation

Hydroxylamine hydrochloride was first prepared [1] by the reduction of ethyl nitrate by means of tin, with hydrochloric acid; hydroxylamine salts have also been prepared by the reduction of nitric acid with metals.[2] The two important

[1] Ann. Suppl. **6**, 220 (1868).

[2] J. Chem. Soc. **43**, 443 (1883); **47**, 597 (1885); **75**, 87 (1899); J. Soc. Chem. Ind. **14**, 595 (1895).

*technical methods consist in the electrolytic reduction of nitric* acid [3] and the action of sodium bisulfite upon sodium nitrite.[4] Raschig, who discovered the latter process for the preparation of hydroxylamine sulfate, has suggested the use of calcium nitrite and bisulfite, so that the bulk of the inorganic salts can be removed in the form of calcium sulfate.[5] The same chemist also showed that sodium hydroxylaminedisulfonate yields acetoxime on treatment with acetone,[6] and it has long been known that acetoxime readily yields hydroxylamine hydrochloride on treatment with hydrochloric acid;[7] but advantage appears only recently [8] to have been taken of these facts in combination.

[3] Zeit. anorg. Chem. **31**, 322 (1902); D. R. P. 133,457 (1902), Chem. Zentr. **1902** (ii), 313; D. R. P. 137,697 (1903), Chem. Zentr. **1903** (i), 106.

[4] Ann. **241**, 161 (1887); D. R. P. 41,987 (1887), J. Chem. Soc. **54**, 913 (1888); J. Chem. Soc. **69**, 1665 (1896); **77**, 673 (1900); J. Am. Chem. Soc. **40**, 1281 (1918).

[5] D. R. P. 216,747 (1910), Chem. Zentr. **1910** (i), 308.

[6] Ann. **241**, 187 (1887).

[7] Ber. **16**, 170 (1883).

[8] *J. Am. Chem. Soc.* **45**, *188 (1923).*

## XIX

## MERCURY DI-*p*-TOLYL

$$2CH_3 \cdot C_6H_4 \cdot HgCl + 4NaI \rightarrow (CH_3 \cdot C_6H_4 \cdot)_2Hg + 2NaCl + Na_2HgI_4$$

Prepared by F. C. Whitmore, N. Thurman, and Frances H. Hamilton.
Checked by J. B. Conant and F. C. Whidden.

### 1. Procedure

In a 2-l. round-bottom flask fitted with a reflux condenser and an efficient glass stirrer, are placed 700 cc. of 95 per cent ethyl alcohol, 100 g. of recrystallized *p*-tolylmercuric chloride (p. 99), and 160 g. of sodium iodide (80 per cent excess). This mixture is boiled with vigorous stirring (Note 2) for fifteen hours; the solid does not entirely enter into solution at any time. The mixture is then thoroughly cooled and filtered by suction and the solid washed with water until free of inorganic halide. It is then dried in an air-oven at 40° and recrystallized from 500 cc. of boiling xylene (Note 3). In this way 45–50 g. (78–85 per cent of the theoretical amount) of a product melting at 238° is obtained.

### 2. Notes

1. Mercury compounds of the type R.Hg.X can be changed to those of the type $R_2Hg$, by almost any neutral or alkaline reagent which tends to change mercuric ions to metallic mercury or to a stable complex ion. Some of these reagents are inorganic iodides, thiocyanates, thiosulfates, sulfides, hydrosulfites, ferrous hydroxide, sodium amalgam, metallic sodium, and sodium stannite. Preliminary experiments indicated that potassium thiocyanate was the best reagent for preparing the mercury

ditolyl, but it was later found that the use of sodium iodide with vigorous stirring gave even better results.

2. Stirring decreases the time required for the reaction and increases the yield. Without stirring it is practically impossible to obtain a product which is free from halogen.

3. Since the mercury ditolyl has practically the same solubility in xylene as the tolylmercuric iodide and chloride, the latter will be present in the recrystallized product if the reaction has not gone to completion. A trace of unchanged product may readily be detected by the metallic sodium test for inorganic halides.

### 3. Other Methods of Preparation

Mercury di-*p*-tolyl has also been prepared by boiling *p*-bromotoluene with sodium amalgam in xylene in the presence of ethyl acetate as a catalyst.[1]

[1] Ann. **154**, 171 (1870); Compt. rend. **68**, 1298 (1869); Ann. **201**, 246 (1880).

XX

# METHYLAMINE HYDROCHLORIDE

$$2HCHO + NH_4Cl \rightarrow CH_3NH_2 \cdot HCl + HCO_2H$$

Prepared by C. S. Marvel and R. L. Jenkins.
Checked by J. B. Conant and F. C. Whidden.

## 1. Procedure

In a 5-l. round-bottom flask fitted with a stopper holding a condenser set for downward distillation and a thermometer which will extend well into the liquid, are placed 4000 g. of technical formaldehyde (35–40 per cent; sp. gr. 1.078 at 20°) and 2000 g. of technical ammonium chloride. The mixture is heated on the steam bath until no more distillate comes over and then over a flame until the temperature of the solution reaches 104°. The temperature is held at this point until no more distillate comes over (four to six hours). The distillate, which consists of methylal, methyl formate and water, may be treated as described in Note 3.

The contents of the reaction flask are cooled to room temperature (Note 1), and the ammonium chloride which separates is filtered off and centrifuged (Note 2). The mother liquor is concentrated on the steam bath under reduced pressure to 2500 cc., and again cooled to room temperature, whereupon a second crop of ammonium chloride is obtained. The total recovery of ammonium chloride up to this point amounts to 780–815 g.

The mother liquor is again concentrated under reduced pressure until crystals begin to form on the surface of the solution (1400–1500 cc.). It is then cooled to room temperature and a first crop of methylamine hydrochloride, containing some ammonium chloride, is obtained by filtering the cold solution

and centrifuging the crystals (Note 2). At this point 625–660 g. of crude product is obtained. The mother liquor is now concentrated under reduced pressure to about 1000 cc. and cooled, a second crop of methylamine hydrochloride (170–190 g.) is then filtered off and centrifuged. This crop of crystals is washed with 250 cc. of cold chloroform, filtered and centrifuged, in order to remove most of the dimethylamine hydrochloride which is present; after the washing with chloroform the product weighs 140–150 g. The original mother liquor is then evaporated under reduced pressure, as far as possible, by heating on a steam bath, and the thick syrupy solution (about 350 cc.) which remains is poured into a beaker and allowed to cool, with occasional stirring, in order to prevent the formation of a solid cake (Note 1). The thick paste so obtained is centrifuged, and the crystals (170–190 g.) are washed with 250 cc. of cold chloroform; the solution is filtered and the crystals are centrifuged, thus yielding 55–65 g. of product. There is no advantage in further concentrating the mother liquor.

The total yield of crude centrifuged methylamine hydrochloride is 830–850 g. This product contains, as impurities, water, ammonium chloride, and some dimethylamine hydrochloride. In order to obtain a pure product, the crude methylamine hydrochloride is recrystallized from absolute alcohol (Note 4). The crude salt is placed in a 5-l. round-bottom flask fitted with a reflux condenser protected at the top with a calcium chloride tube; 2 l. of absolute alcohol is added and the mixture heated to boiling. After about half an hour the undissolved material is allowed to settle and the clear solution is poured off. When the alcoholic solution is cooled, methylamine hydrochloride crystallizes out. It is filtered off and centrifuged, and the alcohol used for another extraction. The process is repeated until the alcohol dissolves no more of the product (about five extractions are necessary). In the flask 100–150 g. of ammonium chloride remains, making the total recovery of ammonium chloride 850–950 g. The yield of recrystallized methylamine hydrochloride is 600–750 g. (45–51 per cent of the theoretical amount, based on the ammonium chloride used up in the process).

## 2. Notes

1. The methylamine hydrochloride solutions should be cooled rapidly in order to bring the salt down in small crystals which may be easily purified.

2. Centrifuging the precipitates is the only satisfactory method of drying, as all of the products tend to take up water when allowed to stand in the air.

3. Methylal and sodium formate may be obtained from the first distillate of the main reaction mixture. The crude distillate is placed in a flask fitted with a reflux condenser and to it is added a solution of 200 g. of sodium hydroxide in 300 cc. of water. The methyl formate is hydrolyzed to sodium formate. The methylal layer is separated, dried over calcium chloride and distilled. In this way 240–260 g. of methylal, boiling at 37–42°, is obtained. By evaporating the watery portion to dryness there is obtained a residue of about 280 g. of crude sodium formate.

4. Since ammonium chloride is not absolutely insoluble in 100 per cent ethyl alcohol (100 g. dissolve 0.6 g. at 15°) the methylamine hydrochloride purified in the manner described contains appreciable traces of it. A purer product can be prepared by recrystallizing from *n*-butyl alcohol, in which the solubility of ammonium chloride even at the boiling temperature is negligibly small. Methylamine hydrochloride is somewhat less soluble in this solvent than in ethyl alcohol, but as a rule three extractions carried out at 90–100° with 4–6 parts of fresh butyl alcohol for each extraction result in a substantially complete separation. Since the last traces of the solvent are not readily removed by exposure to air, a solution of the recrystallized material in a small quantity of water should be distilled until free of alcohol, and allowed to crystallize.

5. The literature[1] claims a yield of methylamine hydrochloride amounting to 79 per cent of the weight of ammonium chloride used up in the reaction. This figure is probably based

[1] J. Chem. Soc. **111**, 850 (1917).

on the weight of crude methylamine hydrochloride and not of the recrystallized material.

### 3. Other Methods of Preparation

Methylamine occurs in herring brine;[2] in crude methyl alcohol from wood distillation,[3] and in the products obtained by the dry distillation of beet molasses residues.[4] It has been prepared synthetically by the action of alkali on methyl cyanate or iso-cyanurate;[5] by the action of ammonia on methyl iodide,[6] methyl chloride,[7] methyl nitrate,[8] or dimethyl sulfate;[9] by the action of methyl alcohol on ammonium chloride,[10] on the addition compound between zinc chloride and ammonia,[11] or on phospham;[12] by the action of bromine and alkali on acetamide;[13] by the action of sodamide on methyl iodide;[14] by the reduction of chloropicrin,[15] of hydrocyanic or of ferrocyanic acid,[16] of hexamethylenetetramine,[17] of nitromethane,[18] or of methyl nitrite;[19] by the action of formaldehyde on ammonium chloride.[20]

[2] Ber. **18**, 1922 (1885).

[3] Jahresb. **1873**, 686; Ann. chim. phys. (5) **1**, 444 (1874).

[4] Ann. chim. phys. (5) **23**, 316 (1881).

[5] Ann. **71**, 332 (1849).

[6] Ann. **79**, 16 (1851).

[7] Bull. soc. chim. **45**, 499 (1886).

[8] Compt. rend. **48**, 344 (1859); Ann. **110**, 255 (1859); Jahresb. **1862**, 327; Ann. chim. phys. (5) **23**, 321 (1881).

[9] Ber. **43**, 139 (1910); J. Chem. Soc. **117**, 236 (1920).

[10] Ber. **8**, 458 (1875).

[11] Ber. **17**, 639 (1884).

[12] D. R. P. 64,346, Frdl. **3**, 13 (1890–94).

[13] Ber. **15**, 765 (1882); Compt. rend. **147**, 430, 680, 983 (1908).

[14] Compt. rend. **156**, 328 (1913).

[15] Ann. **109**, 282 (1859); **184**, 51 (1877); J. Chem. Soc. **115**, 159 (1919).

[16] Ann. **121**, 139 (1862); **128**, 201 (1863); Z. physik. Chem. **72**, 674 (1910); D. R. P. 264,528, Frdl. **11**, 110 (1912–14).

[17] D. R. P. 73,812, Frdl. **3**, 15 (1890–94); Bull. soc. chim. (3) **11**, 23 (1894); D. R. P. 143,197, Frdl. **7**, 24 (1902–04); D. R. P. 148,054, Frdl. **7**, 26 (1902–04); C. A. **9**, 2232 (1915).

[18] Bull. soc. chim. (3) **21**, 783 (1899); (4) **7**, 954 (1910); Ber. **44**, 2403 (1911).

[19] Bull. soc. chim. (4) **7**, 824 (1910); Ann. chim. phys. (8) **25**, 136 (1912).

[20] Bull. soc. chim. (3) **13**, 534 (1895); Compt. rend. **147**, 429 (1908); J. Chem. Soc. **111**, 848 (1917); J. Am. Chem. Soc. **40**, 1411 (1918).

XXI

## METHYL *m*-NITROBENZOATE

$$C_6H_5 \cdot CO_2CH_3 + HNO_3 \rightarrow NO_2 \cdot C_6H_4 \cdot CO_2CH_3 + H_2O$$

Prepared by OLIVER KAMM and J. B. SEGUR.
Checked by H. T. CLARKE and E. R. TAYLOR.

### 1. Procedure

INTO a 2-l. round-bottom flask fitted with a mechanical stirrer, are placed 400 cc. of concentrated sulfuric acid cooled to 0°, and 204 g. (1.5 mols.) of pure methyl benzoate (Note 1). The mixture is cooled by means of an ice bath to 0–10° and then, with stirring, there is added gradually by means of a dropping funnel a mixture of 125 cc. concentrated nitric acid (sp. gr. 1.42) and 125 cc. concentrated sulfuric acid. During the addition of the nitrating acid, which requires about one hour, the temperature of the reaction mixture should be kept within the range 5–15° (Note 2).

After the nitric acid has been added, stirring is continued for fifteen minutes longer; the mixture is then poured upon 1300 g. of cracked ice. The crude methyl *m*-nitrobenzoate separates as a solid and is filtered off by means of suction and washed with water. The product is placed in a flask and agitated with 200 cc. of ice-cold methyl alcohol in order to remove a small amount of *o*-nitrobenzoic ester and other impurities that are present. The cooled mixture is then filtered by means of suction, washed with another 100-cc. portion of cold methyl alcohol (Note 3), and the solid dried. The yield is 220–230 g. (81–85 per cent of the theoretical amount) of an almost colorless product melting at 74–76°. In order to obtain a product of maximum purity, which melts at 78°, it is advisable to recrystallize the ester from an equal weight of methyl alcohol.

## 2. Notes

1. It is necessary that the methyl benzoate should be of high purity and dissolve in sulfuric acid without color. Commercial methyl benzoate which does not meet the latter specification may give yields about 10 per cent lower.

2. The nitration of methyl benzoate runs unusually smoothly, but it is essential to keep the temperature within the specified limits, otherwise the yield falls; at 50°, 193 g. of solid product is obtained, while at 70° the yield falls to 130 g.

3. On diluting the methyl alcoholic filtrate with water, 10–20 cc. of oil separates; more of this oil is formed by nitrating at higher temperatures, amounting to 57 cc. at 50° and 100 cc. at 70°. The oil consists not merely of methyl *o*-nitrobenzoate with some of the meta compound but contains also traces of dinitrobenzoic ester and nitrophenolic compounds. Unchanged methyl benzoate does not appear to be present.

4. The nitration method is also adaptable to the preparation of ethyl *m*-nitrobenzoate. The yield is, however, slightly lower, owing to the greater solubility of the ethyl ester.

## 3. Other Methods of Preparation

Methyl *m*-nitrobenzoate has been prepared by the esterification of *m*-nitrobenzoic acid; [1] this method is, however, obviously much less satisfactory than nitration of methyl benzoate. Nitration by means of fuming nitric acid has also been applied to methyl benzoate,[2] but the use of the ordinary nitration mixture of concentrated sulfuric acid and concentrated nitric acid is more satisfactory.

[1] Ann. **72**, 275 (1849).
[2] Rec. trav. chim. **17**, 97, 100 (1898).

XXII

## *m*-NITROBENZOIC ACID

$$NO_2 \cdot C_6H_4 \cdot CO_2CH_3 + NaOH \rightarrow NO_2 \cdot C_6H_4 \cdot CO_2Na + CH_3OH$$
$$NO_2 \cdot C_6H_4 \cdot CO_2Na + HCl \rightarrow NO_2 \cdot C_6H_4 \cdot CO_2H + NaCl$$

Prepared by OLIVER KAMM and J. B. SEGUR.
Checked by H. T. CLARKE and E. R. TAYLOR.

### 1. Procedure

IN a 2-l. round-bottom flask fitted with a reflux condenser are placed a solution of 80 g. (2 mols) of sodium hydroxide in 320 cc. of water (Note 1) and 180 g. (1 mol.) of methyl *m*-nitrobenzoate (not recrystallized, p. 71). The mixture is heated to boiling during five to ten minutes or until the saponification is complete as shown by the disappearance of the ester.

The reaction mixture is now diluted with an equal volume of water, and when cool is poured, with stirring, into 250 cc. of concentrated hydrochloric acid (Note 2). After the solution has cooled to room temperature, the *m*-nitrobenzoic acid is filtered off by means of suction. This crude acid when dry weighs 150–160 g. (87–93 per cent of the theoretical amount). It possesses a light brownish color, melts at 140°, and should be completely soluble in ether, thus showing the absence of salts. This acid is satisfactory for many purposes, but in order to prepare a perfectly pure product it must be crystallized once from 1 per cent aqueous hydrochloric acid. A light cream-colored product is thus obtained with a loss of about 5 per cent of the material.

### 2. Notes

1. The use of a more dilute sodium hydroxide solution than that recommended above has been found to yield unsatisfactory

results in the saponification of the ester. Prolonged boiling may lead to the production of colored products.

2. After the hydrolysis of the methyl *m*-nitrobenzoate it is essential that the solution of the sodium salt be poured into the acid. If acid be added to the salt in the usual way, a less soluble acid salt separates; and as this cannot be entirely removed from the *m*-nitrobenzoic acid even on long digestion with hydrochloric acid, a product is obtained which does not dissolve completely in ether.

3. *m*-Nitrobenzoic acid is soluble to the extent of 1 part in 300 parts of water at 20°, and 20 parts at 100°. The crystallization from water or dilute hydrochloric acid is therefore quite satisfactory.

4. *m-Nitrobenzoic acid is obtained in a higher yield by nitra*tion of methyl benzoate (p. 71) with subsequent hydrolysis than by the direct nitration of benzoic acid; this method is also preferable on account of the laborious nature of the methods necessary for the separation of the meta acid from the small quantities of the para isomer formed in the latter process.

### 3. Other Methods of Preparation

*m*-Nitrobenzoic acid has been prepared by the nitration of benzoic acid by means of nitric acid,[1] a mixture of nitric acid and sulfuric acid,[2] or mixtures of nitrates and sulfuric acid;[3] all of these methods lead to the production of a mixture containing principally the *m*-nitrobenzoic acid with a smaller proportion of *o*-nitrobenzoic acid and 1–2 per cent of *p*-nitrobenzoic acid, and the separation of these isomers is troublesome. *m*-Nitrobenzoic acid has also been prepared by the oxidation of the difficultly accessible *m*-nitrotoluene by means of chromic acid mixture[4] or permanganate.[5] It has also been formed by the nitration of hippuric acid with subsequent hydrolysis.[6]

[1] Ann. **34**, 297 (1840); Ann. **222**, 72 (1884).
[2] Ann. **91**, 186 (1854).
[3] Ann. **91**, 185 (1854); Ber. **10**, 862 (1877).
[4] Ann. **155**, 25 (1870).
[5] J. Am. Chem. Soc. **41**, 1569, (1919).
[6] Ann. **78**, 104 (1851).

## XXIII

## p-NITROBENZOYL CHLORIDE

$$NO_2 \cdot C_6H_4 \cdot CO_2H + PCl_5 \rightarrow NO_2 \cdot C_6H_4 \cdot COCl + POCl_3 + HCl$$

Prepared by ROGER ADAMS and R. L. JENKINS.
Checked by OLIVER KAMM.

### 1. Procedure

IN a 3-l. round-bottom flask are mixed 500 g. (1 mol.) of pure *p*-nitrobenzoic acid and 626 g. (1.05 mol.) of pure phosphorus pentachloride (Note 1). The flask is provided with an exit tube leading to the surface of a flask of water, in order to absorb the hydrogen chloride formed during the reaction. The flask is placed on a water bath and heated with occasional shaking until the reaction starts (fifteen to forty-five minutes). Vigorous evolution of hydrogen chloride takes place, and the heating is continued until the reaction is complete (fifteen to thirty minutes after the reaction starts). There is thus formed a light yellow, homogeneous liquid.

The reaction mixture is now transferred to a Claisen flask connected with a water-cooled condenser, and the phosphorus oxychloride is removed at ordinary pressure by raising the temperature of the oil bath (Note 2) gradually to 200–220°. The water condenser is then replaced by a *short* air-cooled condenser and the residual liquid is distilled under reduced pressure (Note 3). A small quantity of phosphorus oxychloride first distils over, after which the receiver is changed and the temperature rises rapidly to the boiling point of *p*-nitrobenzoyl chloride, 197°/73 mm. (155°/20 mm.). During this distillation the oil bath should be kept at a temperature of about 230–250° (or at 210–215° if 20 mm. pressure is used). The yield is 500–534 g. (90–96 per cent of the theoretical amount). The distillate

solidifies to a yellow crystalline mass melting at 71° (Note 4). The product may be recrystallized from ligroin or carbon tetrachloride, from which it separates in fine yellow needles melting at 73°.

## 2. Notes

1. The yield of *p*-nitrobenzoyl chloride depends to a great extent upon the quality of the reagents used. With impure phosphorus pentachloride and pure *p*-nitrobenzoic acid, yields of 70–80 per cent of the product are obtained. With pure phosphorus pentachloride and a less pure grade of *p*-nitrobenzoic acid, yields of 85–90 per cent are obtained. When neither reagent is of high grade, yields may fall as low as 40–50 per cent of the theoretical amount. In all such cases the color of the original reaction mixture varies from a deep yellow to a black.

Phosphorus pentachloride purchased as pure is occasionally of inferior quality and gives poor results. It is not a difficult matter to prepare in the laboratory a product suitable for this reaction. To 1000 g. of phosphorus trichloride, chlorine is added until the increase in weight is 500 g. The gas should be added above the surface of the liquid, which is stirred occasionally during the addition. The stirring should not be continuous, however, as this tends to allow the formation of the pentachloride in the tube, which thus becomes clogged. At the end of the reaction the mixture becomes practically solid.

2. *If the reaction mixture is heated with a free flame during* the distillation under reduced pressure, there is considerable danger of superheating and consequent decomposition (sometimes violent) of the *p*-nitrobenzoyl chloride.

Experience with many preparations of this acid chloride has shown that it is desirable to use, during the distillation under reduced pressure, a safety water-bottle between the receiving flask and the manometer. This avoids the passage of vapors of phosphorus oxychloride or acid chloride into the pump.

3. At the beginning of the distillation under reduced pressure the air condenser is warmed gently with a free flame to prevent solidification of the first portion of the distillate.

4. The product is best placed while hot in small wide-mouth bottles and allowed to solidify. This prevents any moisture from the air from decomposing more than the surface layer of the acid chloride.

## 3. Other Methods of Preparation

*p*-Nitrobenzoyl chloride has been prepared only by the action of phosphorus pentachloride on *p*-nitrobenzoic acid.[1]

[1] Ann. **221**, 335 (1883).

# XXIV

## *m*-NITROCHLOROBENZENE

$$NO_2 \cdot C_6H_4 \cdot NH_2 + HCl + NaNO_2 \rightarrow NO_2 \cdot C_6H_4 \cdot N_2Cl + NaCl + 2H_2O$$

$$NO_2 \cdot C_6H_4 \cdot N_2Cl + CuCl \rightarrow NO_2 \cdot C_6H_4 \cdot Cl + N_2 + CuCl$$

Prepared by W. W. HARTMAN and M. R. BRETHEN.
Checked by C. S. MARVEL and C. R. NOLLER.

### 1. Procedure

To a solution of 1200 g. of copper sulfate and 400 g. of sodium chloride in 4 l. of water at 60–70° is added a concentrated solution of 200 g. of (90–95 per cent) sodium bisulfite (prepared if desired by saturating with sulfur dioxide a solution of 100 g. of sodium carbonate). The white precipitate of cuprous chloride is filtered off, sucked dry as rapidly as possible, and suspended in a mixture of 2 l. of water and 1500 cc. of concentrated hydrochloric acid (Note 1).

In the meantime, 552 g. of good commercial *m*-nitroaniline, melting at 110° or above (Note 2), is dissolved in a mixture of 500 cc. of hydrochloric acid and 1 l. of hot water; 1100 cc. of hydrochloric acid is then added, and the solution is cooled rapidly, with stirring. It is then surrounded with a freezing mixture, and diazotized at a temperature below 1° by adding, with constant stirring, a solution of 288 g. of technical (95 per cent) sodium nitrite in 700 cc. of water, care being taken to avoid adding an excess over that necessary to produce a distinct reaction with starch-iodide paper (cf. pp. 7–8). This point is reached when all but about 25 cc. of the nitrite solution has been added; the addition requires about an hour and a half. The cold solution is now filtered in order to remove some amorphous insoluble matter; this solid, when dry, weighs 50–55 g.

The clear filtrate, which has only a pale yellow color, is now run, with stirring, into the cuprous chloride solution in a 12-l. flask, while the temperature is kept at 25–30° (Note 3). A somewhat sticky precipitate first forms, which later becomes crystalline; nitrogen is evolved in a continuous stream. The addition requires about thirty minutes. The mixture is then warmed on a steam bath under an efficient reflux condenser until the evolution of nitrogen ceases. It is then distilled in a current of steam (using the apparatus described in Vol. II, pp. 80–82) until no more nitrochlorobenzene passes over; 9–10 l. of distillate collects during this process (Note 4). When quite cold, the water is decanted off, and the solid shaken with 1–2 l. of 1 per cent sodium hydroxide solution at 50°. The mixture is again allowed to cool, and the light yellow alkaline solution is decanted from the solid product, which is then collected on a filter, washed with a little cold water, dried, and distilled under reduced pressure. It boils completely at 116–117°/12 mm. or 124–125°/18 mm., and the distillate solidifies to 430–450 g. (68–71 per cent of the theoretical amount) of a pale yellow solid which melts at 44–45°.

## 2. Notes

1. It is more convenient to prepare cuprous chloride by reducing copper sulfate with sodium bisulfite than by the action of copper upon cupric chloride (see also p. 33). It is well to test a sample of the filtrate with sodium bisulfite solution; no further cuprous chloride should separate.

2. The yield will, of course, depend upon the quality of the nitroaniline. The pure amine would yield none of the insoluble substance on diazotization, but the cost of purification would be prohibitive. It may be noted that if the weight of the insoluble residue be deducted, the yield amounts to 75–78 per cent of the theoretical amount.

3. It is important that the temperature should be held at 25–30° during the addition of the diazonium chloride to the cuprous chloride solution. At lower temperatures the decomposition of the unstable additive compound proceeds too slowly,

and would cause too violent an evolution of nitrogen on warming; at higher temperatures the formation of tarry by-product increases.

4. If desired, the steam distillation may be omitted, since the proportion of non-volatile resinous impurities is very low. In this case the reaction mixture is allowed to cool, and the watery solution is decanted; the residue is then dissolved in 1–2 l. of benzene, and the benzene solution washed with water and with dilute alkali, after which the solvent is removed by distillation on the steam bath and the residue distilled under reduced pressure. The yield and purity of the final product are equally satisfactory.

An iron condenser should not be used in the steam distillation of the crude *m*-nitrochlorobenzene, as some reduction takes place and the yield is lowered by 10 to 15 per cent. The product is also deeply colored.

### 3. Other Methods of Preparation

*m*-Nitrochlorobenzene is not formed when chlorobenzene is nitrated, but is the chief product of the chlorination of nitrobenzene. The reaction takes place with difficulty, and it is necessary to use a catalyst, such as iodine,[1] ferric chloride [2] or antimony trichloride.[3]

The replacement of one nitro group in *m*-dinitrobenzene by a chlorine atom by means of partial reduction and diazotization has been described by Griess.[4]

[1] Ber. **7**, 1765 (1874).
[2] J. prakt. Chem. (2) **36**, 25 (1887).
[3] Ann. **182**, 102 (1876).
[4] Jahresber. **1863**, 423; **1866**, 457.

XXV

## NITROMETHANE

$$Cl \cdot CH_2 \cdot CO_2Na + NaNO_2 \rightarrow NO_2 \cdot CH_2 \cdot CO_2Na + NaCl$$
$$NO_2 \cdot CH_2 \cdot CO_2Na + H_2O \rightarrow NO_2 \cdot CH_3 + NaHCO_3$$

Prepared by F. C. WHITMORE and MARION G. WHITMORE.
Checked by H. T. CLARKE and J. H. BISHOP.

### 1. Procedure

To a mixture of 500 g. of chloroacetic acid and 500 g. of cracked ice, is added, with stirring, just sufficient cold 40 per cent sodium hydroxide solution to make the solution faintly alkaline to phenolphthalein. About 360 cc. is required; the temperature should not rise above 20° (Note 1). The solution is then mixed with 365 g. of sodium nitrite dissolved in 500 cc. of water and heated in a 3-l. round-bottom flask fitted with a two-hole stopper containing a bent tube of large diameter connecting with an efficient condenser (set downward for distillation) and a thermometer dipping into the liquid. The receiver should be so arranged that it can be cooled, if necessary, by a stream of water.

The solution is heated slowly until the first appearance of bubbles of carbon dioxide, which occurs when the temperature has reached about 80°. The flame is then removed and the reaction allowed to proceed by itself (Note 2). If no rise in temperature occurs, heat is very cautiously applied until the temperature rises to 85°, when the flame is again removed. At this temperature the exothermic decomposition of the sodium nitroacetate becomes so rapid that the temperature rises almost to 100° without further application of external heat. If heat is applied after the temperature of the liquid reaches 85°, violent frothing will occur, with serious loss of nitromethane. If the

reaction becomes too vigorous it may be checked by applying a wet towel to the flask. Nitromethane starts to distil over at about 90°. During the spontaneous heating, about 120 cc. of nitromethane distils over, accompanied by about 170 cc. of water (Note 3). This water is saved for redistillation.

When the mixture ceases to maintain its temperature spontaneously at 95–100°, heat is applied cautiously until the temperature reaches 110°. About 13 cc. of nitromethane and 200 cc. of water distil over. Further distillation gives water which contains too little nitromethane to pay for recovery. At this point enough sodium chloride and sodium carbonate have separated to cause serious bumping.

The water separated from the nitromethane distillates is mixed with one-quarter of its weight of salt, and redistilled, yielding 10–12 cc. of nitromethane and about 100 cc. of water. This water on distillation gives 3–4 cc. of nitromethane and about 45 cc. of water (Note 4).

The total yield of moist product is 125–135 g.; on drying with a little calcium chloride and distilling, 115–125 g. of pure nitromethane, boiling at 98–101°, is obtained (35–38 per cent of the theoretical amount). A small forerun distils over below 98° and a little dark brown residue remains.

## 2. Notes

1. In making the sodium chloroacetate, the use of sodium hydroxide with proper cooling is much more rapid than the use of sodium carbonate. In the case of sodium hydroxide it is essential to keep the solution cool in order to prevent the formation of sodium glycollate. If it is preferred to employ sodium carbonate, about 300 g. of the anhydrous material will be required to make the solution slightly alkaline.

2. The thermometer dipping *in the liquid* is absolutely necessary, as the success of the preparation depends on proper temperature control. The vital point of the whole preparation is to remove all external heat as soon as the reaction is well started. This is between 80 and 85°. No frothing ever occurs when this precaution is rigidly adhered to.

3. It has been recommended [1] that use be made of a gravity separator connected with the adapter in order to separate the nitromethane as fast as it condenses. It was found inadvisable to use such a separator, as the nitromethane is so little heavier than water that a rapid separation is not possible; drops of nitromethane remain suspended and pass over with the water. It is best to allow the distillates to stand in cylinders for at least half an hour before separating the nitromethane by means of a separatory funnel. During this standing, as much as 2 per cent more of nitromethane sometimes settles out.

4. If the time consumed is an important consideration, it is well to note that the spontaneous heating from 85 to 100° gives three-quarters of all the nitromethane obtained in the preparation. This takes less than one hour. The further heating above 100° and the distillations of the water layers take over two hours, and give only one-quarter of the total yield.

5. Several of these distilling sets can be set up and run by one operator, if each lot is started only when the preceding one has reached 85° and external heat has been removed. The corresponding water layers from different sets can be united and distilled at once.

### 3. Other Methods of Preparation

Nitromethane has been prepared by the action of methyl iodide on silver nitrite; [2] by the action of methyl sulfate on potassium nitrite; [3] by the oxidation of methylamine by Caro's reagent; [4] by the interaction of potassium nitrite and potassium chloroacetate,[5] or, preferably,[1] the corresponding sodium salts.[6] The use of the calcium salts was found to be of no advantage.[1] The only one of the above methods to be studied was the interaction of the sodium salts in boiling aqueous solution.

[1] Ber. **42**, 3438 (1909).
[2] Ann. **171**, 32 (1874).
[3] Ber. **40**, 3216 (1907).
[4] Ber. **35**, 4300 (1902).
[5] J. prakt. Chem. (2) **5**, 427 (1872); (2) **8**, 316 (1874); Ber. **41**, 4457 (1908).
[6] Bull. soc. chim. (3) **23**, 333 (1900); (4) **5**, 180 (1909).

## XXVI

## *m*-NITROPHENOL

$$NO_2 \cdot C_6H_4 \cdot NH_2 + H_2SO_4 + HNO_2 \rightarrow NO_2 \cdot C_6H_4\ N_2 \cdot OSO_3H$$
$$NO_2 \cdot C_6H_4 \cdot N_2 \cdot OSO_3H + H_2O \rightarrow NO_2 \cdot C_6H_4 \cdot OH + N_2 + H_2SO_4$$

Prepared by Roger Adams and W. C. Wilson.
Checked by Oliver Kamm and A. O. Matthews.

### 1. Procedure

In a 500-cc. round-bottom flask are placed 200 cc. of water, 100 cc. of concentrated sulfuric acid, and 50 g. of powdered *m*-nitroaniline. The hot mixture is shaken until solution is complete, and the hot *m*-nitroaniline sulfate solution is then poured into a 5-l. flask containing 1000 cc. of water and 800–1000 g. of cracked ice. During this procedure there must be good agitation, so that the *m*-nitroaniline sulfate forms a finely divided precipitate. Generally, the amount of ice used is sufficient to lower the temperature of the mixture to 0°, but if not, more ice is added till 0° is reached.

A solution of 26 g. of sodium nitrite in 200 cc. of water is then rapidly added (Note 1) to the cold *m*-nitroaniline sulfate suspension; continual shaking or mechanical stirring should be used until the *m*-nitroaniline sulfate dissolves completely. This requires about five minutes, during which period the solution gradually darkens. A small flocculent precipitate forms at the same time and should be filtered off.

A mixture of 6 l. of water and 600 cc. of concentrated sulfuric acid is placed in a 12-l. round-bottom flask, and to it the diazonium salt solution is added all at once; the resulting mixture is then heated to boiling as rapidly as possible. The solution becomes turbid at first but gradually becomes clear after boiling for about forty minutes. The solution, which now contains a

small amount of tarry material, is filtered with suction through a Buchner funnel provided with 2–3 cm. of sand on top of the filter paper.

The filtered solution is now cooled, which causes a small amount of *m*-nitrophenol to separate. This is not filtered off, but the whole solution is extracted with ether (750–1000 cc. in

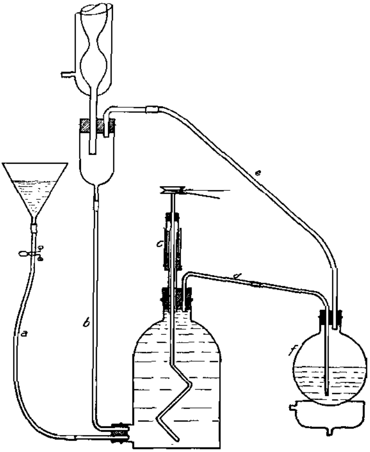



FIG. 3.

the flask and 500–750 cc. in the bottle) in the continuous extractor shown in the accompanying diagram and described in Note 3. About two hours' time is necessary. The ether is distilled off, and the remaining oil, when cooled, solidifies to yellow crystals of crude *m*-nitrophenol. The crystals are transferred to a beaker and washed with a small quantity of cold benzene, to take out most of the yellow color which is present. The yield of this partially purified product amounts to 40–43 g. (80–85 per cent

of the theoretical amount). The cream-colored product thus obtained melts at 90° and is satisfactory for most purposes but may be purified as follows: the *m*-nitrophenol is dissolved in hot hydrochloric acid (1 part of concentrated hydrochloric acid to 1 part of water, by volume), filtered and cooled to 0°, when light yellow crystals separate. An alternative method is to distil under reduced pressure (b. p. 182–189°/12 mm.) and recrystallize the distillate from benzene; in this way a product which melts at 96° is obtained.

## 2. Notes

1. In diazotizing *m*-nitroaniline sulfate, it is necessary to add the sodium nitrite as rapidly as possible in order to prevent any of the diazonium salt from coupling with undiazotized *m*-nitroaniline and forming a yellow precipitate of diazoamino compound. The presence of the excess of sulfuric acid, which does not interfere with the formation of the *m*-nitrophenol, tends to avoid this same difficulty.

2. The hydrolysis of the diazonium salt must be carried out in a dilute solution. A higher concentration greatly increases the amount of tar formed and diminishes the yield of *m*-nitrophenol. Moreover, the amount of tar formed is less, provided the solution of diazonium salt and dilute sulfuric acid is raised to the boiling point as rapidly as possible.

3. The apparatus shown (Fig. 3) is a very convenient form of continuous extractor for the laboratory. In the flask *f* is placed two-thirds of the solvent to be used for the extraction. The remainder is placed in the bottle, which should be just large enough to accommodate the solution to be extracted and the rest of the solvent. The flask is heated on a bath, causing the vapors to pass through *e* into the condenser, and the liquid therefrom flows through *b* into the bottom of the bottle, the contents of which must be mechanically stirred during the extraction in order to obtain efficient contact of the liquids. The stirrer and mercury seal are represented by *c*. For emptying and filling the bottle without disconnecting the apparatus,

the tube *a* with pinchcock is provided. The only precaution to be mentioned is that occasionally the solution in the flask *f* becomes too concentrated, and consequently so hot that the ether cannot flow back through *d* owing to its rapid vaporization. If this happens, the contents of the flask must be removed and replaced by fresh solvent.

There is no value in adding salt to the solution before extraction.

The ether recovered amounts to 1000–1100 cc.

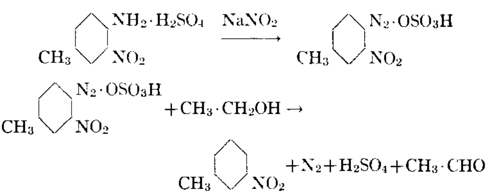
### 3. Other Methods of Preparation

*m*-Nitrophenol has been made by diazotizing *m*-nitroaniline and subsequently heating with a large volume of water.

[1] Ber. **7**, 179 (1874); Ann. **215**, 323 (1882); Rec. trav. chim. **2**, 216 (1883).

XXVII

## *m*-NITROTOLUENE




Prepared by H. T. Clarke and E. R. Taylor.
Checked by J. B. Conant and L. F. Lea.

### 1. Procedure

To 500 g. of 95 per cent ethyl alcohol in a 5-l. flask are added 170 g. of "*m*-nitro-*p*-toluidine" (3-nitro-4-aminotoluene, m. p. 112–114°, Note 1) and 250 g. of concentrated sulfuric acid. The solution is chilled to 10° by means of an ice bath, and a solution of 85 g. of technical sodium nitrite in a minimum quantity of water is slowly added, with stirring, the temperature being kept below 10°. The mixture is now warmed very gently on the water bath under an efficient reflux condenser (from the upper end of which a tube leads to a hood or through water) until evolution of gas ceases (Note 2). The alcohol and aldehyde are then carefully distilled off, using a fractionating column and heating in an oil or brine bath (Note 3); when the temperature of the vapors reaches 80° fractionation is stopped and the residue is distilled in a current of steam. The oil is separated from the distillate and the aqueous portion shaken out once with 150–200 cc. of benzene. The united oil and extract are dried with a

small quantity of calcium chloride and distilled, first under normal pressure to remove the benzene, and finally under reduced pressure. The *m*-nitrotoluene passes over entirely at 113–114°/15 mm. On cooling it forms a pale yellow solid which melts at 16°. The yield of pure material is 95–110 g. (67–77 per cent of the theoretical amount).

## 2. Notes

1. "*m*-Nitro-*p*-toluidine" of good quality is readily available, since it is employed as an intermediate in the preparation of certain important pigments.

2. The decomposition of the diazonium sulfate in the presence of alcohol may take place with considerable violence, and it is necessary to watch the reaction carefully so as to be able to check it, if necessary, by the external application of cold water. Acetaldehyde is rapidly evolved, and some will generally escape from the condenser. It is therefore advisable to lead the escaping gases through water, not only in order to avoid possibility of fire, but to retain any nitrotoluene which may be entrained.

3. If after the reaction the alcohol be distilled off without the use of a column it will contain an appreciable quantity of *m*-nitrotoluene, amounting to 5 or more per cent of the yield. The use of an oil or brine bath is recommended on account of the presence of solid inorganic salts in the mixture.

## 3. Other Methods of Preparation

*m*-Nitrotoluene is formed in very small amount during the nitration of toluene; its presence was first proved by the isolation of *m*-nitrobenzoic acid from the mixture of acids produced on oxidation.[1] It has actually been isolated in a nearly pure condition from the oily by-product obtained in the manufacture of dinitrotoluene, by taking advantage of the fact that it is much less easily nitrated than either the ortho or the para isomer.[2]

[1] Ber. **12**, 443 (1879).
[2] Ber. **18**, 1336 (1885).

The method of preparation adopted is substantially that of Buchka,[3] as this is the only one of practical value. *m*-Nitrotoluene has been obtained by a similar process from 5-nitro-2-aminotoluene [4] (obtained by nitration of acetyl-*o*-toluidine), but this compound is not commercially available, and gives a poor product unless carefully purified.

[3] Ber. **22**, 829 (1889); *cf.* J. Amer. Chem. Soc. **41**, 1565 (1919).
[4] Ann. **158**, 348 (1871).

## XXVIII

## PHENYLUREA

*(by-product, Carbanilide)*

$$C_6H_5 \cdot NH_2 \cdot HCl + CO(NH_2)_2 \rightarrow C_6H_5 \cdot NH \cdot CO \cdot NH_2 + NH_4Cl$$

$$C_6H_5 \cdot NH_2 \cdot HCl + C_6H_5 \cdot NH \cdot CO \cdot NH_2 \rightarrow (C_6H_5 \cdot NH)_2CO + NH_4Cl$$

Prepared by Tenney L. Davis and K. C. Blanchard.
Checked by C. S. Marvel and W. B. King.

### 1. Procedure

A solution of 390 g. of aniline hydrochloride (3 mols) and 190 g. of urea (3.16 mols) in 1500 cc. of water is boiled in a 3-l. flask under a reflux condenser (Note 2). After about one hour, crystals begin to separate; at the end of one and a half to two hours, the mixture, which bumps considerably, is cooled, filtered by suction, and the crystals of carbanilide washed with 100 cc. of boiling water. The filtrate is chilled and the phenylurea which crystallizes out is filtered off and rinsed with a little cold water, the washings being discarded. The filtrate is again boiled under a reflux condenser for one and a half to two hours, or until it begins to bump, and the process is repeated. The above operations are gone through still a third time, and each time the phenylurea is collected from the cold filtrate. The mother liquor is finally evaporated to half its original volume and additional crops of carbanilide and phenylurea are so obtained. Further evaporation is not profitable.

The crude carbanilide (symmetrical diphenylurea) is practically pure, and may be obtained in large colorless needles melting at 235° by recrystallization from alcohol with the use of decolorizing carbon; 1 l. of alcohol is required for every 25 g. of

product (Note 3). The weight of the crude carbanilide is 122–128 g. (38–40 per cent of the theoretical amount).

The crude phenylurea is somewhat colored and contains a little carbanilide. It may be purified by dissolving in a minimum quantity of boiling water, adding a little decolorizing carbon, and filtering. When the filtrate first begins to cool, a flocculent precipitate of carbanilide is deposited; this must be filtered off while the liquid is still hot. The filtrate, on cooling, yields colorless stout needles or flakes of phenylurea melting at 147° (Note 4). The total weight of pure product is 212–225 g. (52–55 per cent of the theoretical amount).

## 2. Notes

1. The reaction can undoubtedly be explained by the formation of an equilibrium mixture of urea and ammonium cyanate in boiling solution; the ammonium cyanate reacts at the moment of its formation with aniline hydrochloride, yielding phenylurea. This latter compound also undergoes a secondary reaction, involving the intermediate formation of phenyl isocyanate, which reacts with aniline hydrochloride forming carbanilide; so that in order to obtain the best yield it is necessary to interrupt the process from time to time and remove the phenylurea first formed.

That the reaction proceeds to completion under the above conditions is shown by the fact that while the mixture ultimately becomes faintly alkaline (on account of the formation of ammonia by hydrolysis of the excess of urea) at no time does the mixture appear to contain aniline.

2. In the above directions the concentration is as high as it is safe to make it; if less water be used the yield of phenylurea decreases and there is grave danger of loss due to the sudden heating of the mixture by rapid separation of crystals. This phenomenon has been observed with a more concentrated mixture even on heating on the steam bath.

3. The carbanilide can also be obtained in long needles from glacial acetic acid or preferably ethyl acetate.

4. If the solution of phenylurea be allowed to cool slowly, the product separates in needles several centimeters in length.

### 3. Other Methods of Preparation

Of the various published methods of preparing phenylurea, such as treatment of aniline salts with potassium cyanate in water solution,[1] heating aniline with urea,[2] with cyanic acid,[3] or with cyanogen chloride,[4] and the interaction of phenyl isocyanate or phenylcarbamine chloride with ammonia,[5] the only ones to be considered as practical methods for preparation are the first two. The first suffers from the disadvantage that potassium cyanate is not easily prepared in the laboratory and rapidly undergoes spontaneous decomposition in storage; while by the action of urea on aniline alone, carbanilide is formed in rather larger proportion than phenylurea.

While the preparation of phenylurea itself by the foregoing process does not appear in the older literature, an analogous process has been patented for the preparation of *p*-phenetylurea,[6] in which *p*-phenetidine is heated with urea nitrate (or *p*-phenetidine hydrochloride with urea) in aqueous solution. This reaction appears to be generally applicable to aromatic primary amines; it does not, however, appear to be so well suited to the preparation of the corresponding derivatives of secondary amines.

[1] Ann. **57**, 265 (1846); Ber. **9**, 820 (1876).
[2] Ber. **9**, 995 (1876); J. Am. Chem. Soc. **44**, 2600 (1922).
[3] J. Chem. Soc. **77**, 33 (1900).
[4] Ann. **70**, 130 (1849).
[5] Ann. **74**, 13 (1850); Am. Chem. J. **16**, 72 (1894).
[6] D. R. P. 76,596, Frdl. **4**, 1268 (1894–97).

## XXIX

## p-TOLYLMERCURIC CHLORIDE

$$CH_3 \cdot C_6H_4 \cdot SO_2Na \cdot 2H_2O + HgCl_2 \rightarrow CH_3 \cdot C_6H_4 \cdot HgCl + NaCl + SO_2 + 2H_2O$$

Prepared by F. C. WHITMORE, FRANCES H. HAMILTON and N. THURMAN.
Checked by J. B. CONANT and F. C. WHIDDEN.

### 1. Procedure

To 1 l. of boiling water in a 3-l. beaker or large evaporating dish (Note 1) is added 150 g. of mercuric chloride; to this mixture is then added, with good stirring, 116 g. of sodium *p*-toluenesulfinate (Vol. II, p. 89). A thick, white, curdy precipitate forms at once (Note 2), and in a short time sulfur dioxide is evolved copiously. The heating and stirring are continued until no more sulfur dioxide is evolved, which requires about two hours.

The mixture is then filtered by suction, and the precipitate dried in an oven at about 80° for twelve hours. The dry precipitate is then placed in a 1-l. round-bottom flask with reflux condenser, and covered with 800 cc. of xylene. The mixture is agitated by shaking, the xylene heated to boiling for five to ten minutes, and the solution filtered through a hot funnel to remove the calomel which is formed during the reaction. The filtrate is cooled, the *p*-tolylmercuric chloride filtered off, and the first precipitate extracted again with the filtrate. This is repeated twice. In this way 90–100 g. (51–57 per cent of the theoretical amount) of a product which melts at 233° is obtained.

## 2. Notes

1. It is essential that the vessel employed should be of at least 3 l. capacity. If it be smaller, the contents will probably overflow during the first evolution of sulfur dioxide.

2. A large amount of calomel is formed in this reaction owing to the reduction of the mercuric chloride by the sulfurous acid formed. This reduction produces hydrochloric acid which probably changes some of the mercury compound to toluene and mercuric chloride. An attempt was made to avoid this action by adding sodium hydroxide slowly during the process to keep the solution from becoming strongly acid, but the yield was increased only slightly. The yield was not increased by adding the sulfinate to the mercuric chloride gradually or by reversing this process.

3. There is always a considerable amount of inorganic mercury left in the filtrate, which gives very little more of the tolylmercuric chloride when treated with more of the sulfinate. This may be present largely in the form of the mercuric salt of *p*-toluenesulfonic acid produced by the oxidation of some of the sulfinic acid liberated in a side-reaction.

## 3. Other Methods of Preparation

*p*-Tolylmercuric chloride has been prepared from *p*-toluenesulfinic acid and mercuric chloride,[1] from *p*-toluenesulfochloride and mercury diphenyl at 120°,[2] by treating *p*-tolueneboric acid with mercuric chloride,[3] by the direct mercuration of toluene with mercuric acetate,[4] from *p*-tolylmercuric nitrate and hydrochloric acid,[5] from hydrochloric acid and *p*-tolylmercuric hydroxide formed by the oxidation of mercury di-*p*-tolyl,[6] and from mercury di-*p*-tolyl by heating with mercuric chloride in alcohol.[7]

[1] Ber. **38**, 2569 (1905).
[2] Ber. **18**, 249 (1885).
[3] Ber. **15**, 185 (1882).
[4] Ber. **32**, 761 (1899); *cf.* Ann. **413**, 329 (1917).
[5] Ber. **31**, 1528 (1898).
[6] J. prakt. Chem. (2) **29**, 138 (1884).
[7] J. prakt. Chem. (2) **1**, 185 (1870).

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